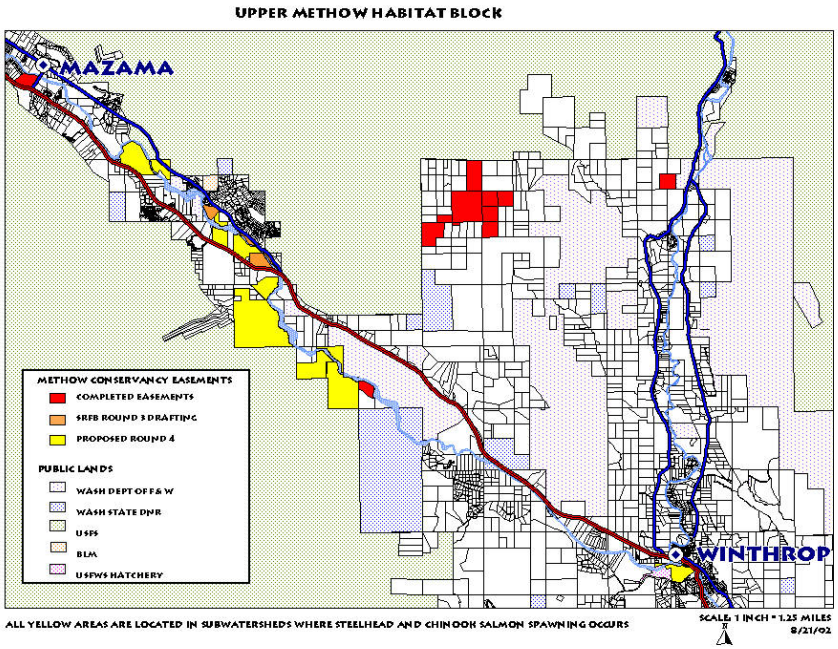
PROTOCOL
FOR
MONITORING EFFECTIVENESS
OF
HABITAT PROTECTION PROJECTS
(Land Parcel Biodiversity Health)

MC-10

Washington Salmon Recovery Funding Board

May 2004



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ORGANIZATION

This document details the monitoring design, procedures and quality assurance Steps necessary to document and report the effectiveness of:

- **Habitat Protection Projects at the Parcel Scale**

This document is in compliance with the Washington Comprehensive Monitoring Strategy (Crawford et al. 2002).

Following are SRFB Objectives for protecting property for salmon recovery through purchases or easements.

1. Protect identified blocks of critical habitat within the ESU, which protect the species at risk from further decline (a conservation area identified for conservancy – a refugia).
2. Protect property providing key linkages connecting fragmented habitats (a parcel that contributes to maintaining key ecological processes).
3. Protect property used to enhance habitat and to offset poor habitat elsewhere in the watershed (habitat enhancement/restoration).

The Board funds two categories of projects related to land acquisition, Restoration/Protection projects and Protection projects. Restoration/Protection projects are specific parcels of land acquired with habitat restoration activities in mind. Protection Projects include lands that the project proponent has prioritized as a high need for acquisition because it meets one of the protection goals already discussed.

A Protection Project is a property acquired either in fee title or a property protected by a restrictive use agreement or easement. Acquisition effectiveness monitoring is limited to Protection Projects because the effects of restoration activities upon the land parcel will confound baseline data.

There are two scales for assessing the effectiveness of habitat acquisitions -- the parcel scale and the watershed scale.

The parcel scale determines whether the desirable attributes of the property in terms of habitat and fish populations have continued at original levels or improved over time. This is purely a local evaluation, and is blind to the overall watershed needs and existing conditions. It only answers the question: ***What is the status of the habitat and fish on acquired lands?*** Is it improving, remaining the same, or declining? The assumption behind this form of effectiveness monitoring is that acquired habitat that

remains unchanged or is improving reflects an effective acquisition. If the habitat is declining, the causes may or may not be directly attributable to changes occurring on the sampled land parcel. For example, there could be activities occurring upstream that affect instream morphology or stream bank structure within the acquisition boundaries.

The watershed scale is more complex but also more directly answers the questions of interest. However, this document does not address those larger questions, such as: How do SRFB acquisitions fit into the overall critical habitat protection needs identified for each watershed? ***Have SRFB acquisitions been effective in addressing watershed habitat protection goals?*** The assumption behind these questions is that we know what needs to occur in a watershed in terms of restoring habitat, providing refuges, and halting habitat destruction. Furthermore, these questions also assume that the needs have been prioritized and have broad support.

This "Effectiveness Monitoring Procedure For Habitat Protection Projects" addresses only the characteristics of the parcels as separate and independent entities (parcel scale). It does not attempt to answer land protection effectiveness monitoring questions at watershed or regional scale.

MONITORING GOAL

Determine whether habitat protection parcels as a whole and individually are effective in maintaining and/or improving salmon habitat and fish and invertebrate species assemblages within the parcel boundaries.

QUESTIONS TO BE ANSWERED

Have the protected properties maintained or improved the riparian habitat benefits for which they were purchased?

Have the protected properties maintained or improved the upland habitat benefits for which they were purchased?

Has the biological condition of the macro-invertebrate and fish species assemblages improved, declined or stayed the same within the protected properties?

NULL HYPOTHESES

Protected property over a 12 year period has had no significant adverse change upon:

- The amount or quality of riparian vegetation and cover.
- The amount or quality of upland vegetation and cover.
- The amount or quality of instream structure and morphology.
- The amount and quality of intertidal vegetation and substrate.
- The macro-invertebrate species assemblages and multi-metric index.
- The native fish species assemblages and index.

OBJECTIVES

BASELINE (YEAR 0)

Determine status of instream, riparian and upland habitat within each randomly selected parcel.

Determine the biological condition of macro-invertebrate and fish species assemblages using a multi-metric index for each randomly selected parcel.

POST-PURCHASE OBJECTIVES (YEARS 3, 6, 9, AND 12)

Determine trends in instream, riparian and upland habitat within each randomly selected parcel compared to the baseline year.

Determine status of macro-invertebrate and fish species assemblages using a multi-metric index for each randomly selected parcel.

RESPONSE INDICATORS

LEVEL 2 INSTREAM MORPHOLOGY

Thalweg Profile. The Thalweg profile characterizes pool-riffle relationships, sediment deposits, wetted width substrate characteristics, and channel unit-pool forming categories. Stream morphology sampling methods are taken from EMAP (Peck et al. unpubl), Section 7.4.

Stream morphology response variables

Indicator Abbreviation	Description
AREASUM	Mean Thalweg vertical profile area for the study reach
RP100	Mean Thalweg residual depth within the study reach
Log10V1WM100	Volume of large woody debris of all sizes within the study reach
CHANL	Study reach bankfull channel capacity
PCT_FN	Mean percent of the study substrate in fines
XEMBED	Mean percentage of the substrate that is embedded within the study reach

LEVEL 2 INTERTIDAL ZONE TRANSECT

Intertidal Zone Transect. Transects will be conducted to quantify vegetation characteristics and bottom substrate of the intertidal zone. Parameters to monitor are taken from NOAA document “Science based Restoration Monitoring of Coastal Habitats” and transects are adapted from grassland transects devised by Joe Arnett, Tetra Tech FW, Inc.

Indicator Abbreviation	Description
ALGAE_M	Percent cover of marine algae
VASCULAR_NNM	Percent cover of non-native herbaceous vascular plants
SLOPE_M	Percent slope from mean high tide to mean low tide
PCT_FNM	Mean percent of the transect substrate in fines

LEVEL 2 RIPARIAN PLANTS

Riparian condition is determined by measuring the plant density and species composition within the study reach. It is also important to measure stream bank erosion. Streamside riparian habitat sampling methods are taken from EMAP (Peck et al. Unpubl.), Section 7.4.

Riparian vegetation response variables

Indicator Abbreviation	Description
XCDENBK	Mean percent shading at the bank (using a densitometer)
XPCMG	Proportion of the reach containing all 3 layers of riparian vegetation, canopy cover, under-story, and ground cover
BANK	Proportion of the reach containing actively eroding stream banks

LEVEL 2 UPLAND PLANTS

Upland habitat can be important to salmon recovery in producing a buffer area between other upland activities and processes and the riparian corridor and stream. Depending upon topography and slope, buffers along streams may need to be much wider than in other areas to protect the stream from erosion and temperature effects. Upland plant community sampling methods are taken from the National Park Service "Fire Monitoring Handbook (FMH)" 2003, and Joe Arnett of Tetra Tech FW, Inc.

Upland vegetation response variables

Indicator Abbreviation	Description
HERB_NN	Percent cover of non-native vascular plant species and percent of coverage of non-native species as measured along five transect segments, each consisting of ten one meter line intercept plots.
SHRUB_NN	Percent cover of non-native shrub species as measured along five transect segments, each consisting of ten one meter line intercept plots.
BA_CONIF	Basal area of conifers per acre (square feet/acre) within five 1/10 acre circular plots
SA_CONIF	Stem count of conifers per acre (number/acre) within five 1/10 acre circular plots
BA_DECID	Basal area of deciduous trees per acre (square feet/acre) within five 1/10 acre circular plots
SA_DECID	Stem count of deciduous trees per acre (number/acre) within five 1/10 acre circular plots

LEVEL 3 FISH SPECIES ASSEMBLAGES

Total abundance of salmon can be determined using both adult counts and juvenile counts. Both adults and juveniles can be monitored using protocols developed by Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife. However, annual variations of salmon abundance located on a particular parcel of land may be the result of changes in variables unrelated to the property monitored. Such things as harvest, ocean conditions, downstream passage, random preferences of the fish may all contribute to annual changes in fish abundance not directly attributable to the property.

Therefore, fish populations in this Procedure are evaluated using an index of biological integrity (IBI) as described by Mebane et al. (2003). Fish species diversity sampling methods are taken from EMAP (Peck et al. Unpubl.), Section 7.4. Procedures summarizing EMAP Table 12-3 and 7-4 are found on page 29. The IBI includes the following indicators of fish assemblage, health and ecosystem quality:

1. Number of native coldwater species
2. Percentage of sensitive native individuals
3. Percentage of coldwater individuals
4. Percentage of tolerant individuals
5. Number of alien species
6. Percentage of common carp
7. Catch per unit effort of coldwater individuals (not applicable to snorkel surveys
8. Percentage of individuals with selected anomalies

Fish assemblage response variable

Indicator Abbreviation	Description
FISHINDEX	Index of Biological Integrity

LEVEL 3 MACRO-INVERTEBRATE ASSEMBLAGES

Stream macro-invertebrate species composition and relative abundance of particular groups show strong correlations with water quality and watershed health factors. Changes in macro-invertebrates would indicate that water quality conditions within the parcel have changed over time. Macro-invertebrate sampling methods are taken from EMAP (Peck et al. unpubl), Section 11. Protocols summarizing EMAP Table 11-2, 11-3, and 11-4 are found on page 35 and in the Department of Ecology's "Benthic Macro-Invertebrate Biological Monitoring Protocols for Rivers and Streams", Publ No. 01-03-028. Indicators considered most sensitive to regional change are compared using a multi-metric index (Karr and Chu, 1999; Wiseman, 2003). The MMI includes the following indicators of stream health based upon invertebrate species composition and relative abundance:

1. Percent of the family Chironomidae of the total sample count
2. Percent of the Orders Ephemeroptera, Plecoptera, and Trichoptera of the total sample count
3. Percent of the Order Ephemeroptera of the total sample count
4. Hilsenhoff Biotic Index (HBI) which is calculated by multiplying the number of individuals of each species by its assigned tolerance value, summing these products, and dividing by the total number of individuals
5. Total number of taxa
6. Number of highly intolerant taxa, as defined by Wiseman (2003)
7. Percent of clinger taxa of the total sample count
8. Number of clinger taxa
9. Number of intolerant taxa with a tolerance value less than 3 (TV3)
10. Percent of the tolerant taxa of the total sample count with a tolerance value greater than 7(TV7)
11. Percent of the top 3 abundant taxa of the total sample count
12. Percent of the filter taxa of the total sample count
13. Percent of the predator taxa of the total sample count
14. Percent of the scraper taxa of the total sample count
15. Number of long-lived taxa

Macroinvertebrate assemblage response variable

Indicator Abbreviation	Description
MMI_INVERT	Macroinvertebrate indicators considered most sensitive to regional change are compared using a multi-metric index (Wiseman, 2003).

SAMPLING PROCEDURE

Elements of the design are as follows:

- Identify the response indicators most sensitive to change and that reflect the attributes that support salmon recovery.
- Establish a randomly selected sub-sample of acquisition projects such that they are representative of the total number of projects completed.
- Insure that enough projects are selected that a significant change is likely to be detected for the response indicators selected.
- Collect a baseline year of sampling to determine status at or near the time of purchase.
- Conduct periodic re-sampling at the same site to determine if significant change occurs for the monitored properties.

METHOD FOR LAYING OUT CONTROL AND IMPACT STREAM REACHES FOR WADEABLE STREAMS

Protocol taken from: ***Peck et al. (Unpubl.), pp. 63-65, Table 4-4; Mebane et al. (2003)***

EQUIPMENT

Metric tape measure, surveyor stadia rod, handheld GPS device, 3 - 2 ft. pieces of rebar painted bright orange, engineer flagging tape, waterproof markers

SAMPLING CONCEPT

The concept of EMAP sampling is that randomly selected reaches located on a stream can be used to measure changes in the status and trends of habitat, water quality, and biota over time if taken in a scientifically rigorous manner per specific protocols. We have applied the EMAP field sampling protocols for measuring effectiveness of restoration and acquisition projects. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These "impact" areas have been matched with "control" areas of the same length and size on the same stream whenever possible.

Within each sampled project reach a series of transects A-K are taken across the stream and riparian zone as points of reference for measuring characteristics of the stream and riparian areas. The transects are then averaged to obtain an average representation of the stream reach.

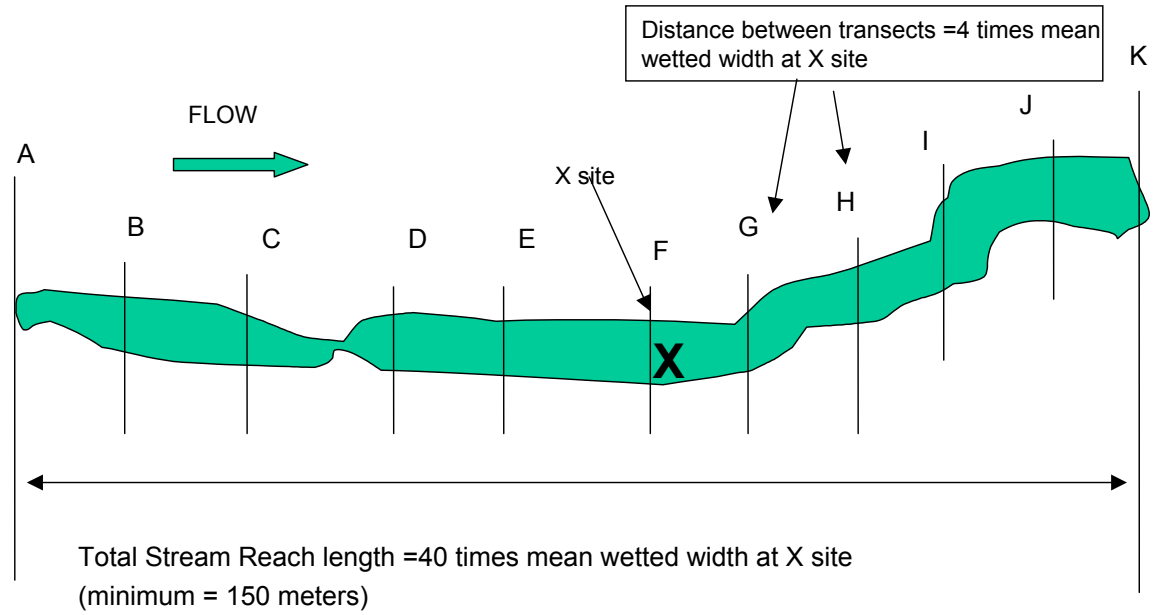

Figure 1. Sampled project reach

LAYING OUT THE TREATMENT AND CONTROL STREAM REACHES

Step 1: Using a handheld GPS device, determine the location of the **X sites** and record latitude and longitude of same on waterproof sheets. The X sites should be considered the center of the Impact and Control study reach. The Impact reach X site must fall within the project affected area. The location of the control X site should be determined based upon the project category and associated procedure (MC-1 to MC-10). Mark the X site on the bank above the high water mark with one of the rebar stakes so that the X site can be found in future years. Use a surveyor's rod or tape measure to determine the wetted width of the channel at five places considered to be of "typical" width within approximately five channel widths upstream and downstream of the X site sample reach location. For streams less than 4 m in width the reach should be at minimum 150 m.

Step 2: Check the condition of the stream upstream and downstream of the X site by having one team member go upstream and one downstream. Each person proceeds until they can see the stream to a distance of 20 times the stream width (equal to one half the sampling reach length) determined in Step 1.

For example if the reach length is determined to be 150 m, each person would proceed 75 m from the X site to lay out the reach boundaries.

NOTE: *For restoration projects less than 40 stream widths, the entire project's length should be sampled and a control area of similar size should likewise be developed within the treatment stream either upstream or downstream as appropriate.*

Step 3: Determine if the reach needs to be adjusted around the X site due to confluences with lower order streams, lakes, reservoirs, waterfalls, or ponds. Also adjust the boundaries to end and begin with the beginning of a pool or riffle, but not in the center of the pool or riffle. Hankins and Reeves (1988) have shown that measures of the variance of juvenile fish populations is decreased by using whole pool/riffles in the sample area.

Step 4: Starting back at the X site, measure a distance of **20 channel widths** down one side of the stream using a tape measure. Be careful not to cut corners. Enter the channel to make measurements only when necessary to avoid disturbing the stream channel prior to sampling activities. This endpoint is the downstream end of the reach and is flagged as transect "A".

Step 5: Using the tape, measure $1/10^{th}$ (4 channel widths in big streams or 15 m in small streams) of the required stream length upstream from the start point (transect A). Flag this spot as the next cross section or transect (transect B).

Step 6: Proceed upstream with the tape measure and flag the positions of nine additional transects (labeled "C" through "K" as you move upstream) at intervals equal to $1/10^{th}$ of the reach length.

METHOD FOR CHARACTERIZING RIPARIAN VEGETATION STRUCTURE

Protocol taken from: ***Peck et al. (Unpubl.), Table 7-10; Kauffman et al. (1999)***

PURPOSE

This protocol is designed to determine the changes in riparian vegetation due to a restoration or acquisition project where riparian vegetation has either been planted or has been protected.

EQUIPMENT

Convex spherical densitometer, field waterproof forms.

SITE SELECTION

The sample reach is laid out according to page 13.

SAMPLING DURATION

Sampling should occur during July-August when vegetation is at its maximum growth.

PROCEDURES FOR MEASURING RIPARIAN VEGETATION AND STRUCTURE

Following are taken from Table 7-10 of EMAP protocols

1. Standing in mid-channel at a cross-section transect (A-K), estimate a 5m distance upstream and downstream (10m length total).
2. Facing the left bank (left as you face downstream), estimate a distance of 10m back into the riparian vegetation or until an exclosure is encountered. On steeply sloping channel margins, estimate the distance into the riparian zone as if it were projected down from an aerial view.
3. Within this 10 m X 10 m area, conceptually divide the riparian vegetation into three layers: a canopy layer (>5 m [16ft] high), an understory (0.5 to 5 m [20 inches to 16ft.] high), and a ground cover layer (<0.5 m high).
4. Within this 10 m X 10 m area, determine the dominant vegetation type for the canopy layer as **Deciduous, Coniferous, broadleaf Evergreen, Mixed, or None.** Consider the layer mixed if more than 10% of the areal coverage is made up of the alternate vegetation type. Indicate the appropriate vegetation type in the "Visual Riparian Estimates" section of the Channel/Riparian Cross Section Form.
5. Determine separately the areal cover class of large trees (>0.3 m [1ft] diameter breast height [DBH]) and small trees (<0.3m DBH) within the canopy layer. Estimate areal cover as the amount of shadow that would be cast by a particular layer alone if the sun were directly overhead. Record the appropriate cover class on the field data form (**"0"= absent: zero cover, "1"= sparse: <10%, "2"= moderate: 10-40%, "3"=heavy: 40-75%, or "4"= very heavy: >75%)**.
6. Look at the understory layer. Determine the dominant vegetation type for the understory layer as described in Step 4.
7. Determine the areal cover class for woody shrubs and saplings separately from non-woody vegetation within the understory, as described.
8. Look at the ground cover layer. Determine the areal cover class for woody shrubs and seedlings, non-woody vegetation, and the amount of bare ground present as described in Step 5 for large canopy trees.
9. Repeat steps 1 through 8 for the right bank.
10. Repeat steps 1 through 9 for all cross-section transects, using a separate field data form for each transect.

Riparian Vegetation Cover	Left Bank					Right bank					Flag
	Canopy (> 5m high)										
Vegetation type	**D**	**C**	**E**	**M**	**N**	**D**	**C**	**E**	**M**	**N**	
Big trees (trunk > 0.3m DBH) XCL	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
Small trees (trunk ,0.3m DBH) XCS	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
	Understory (0.5 to 5m high)										
Vegetation type	**D**	**C**	**E**	**M**	**N**	**D**	**C**	**E**	**M**	**N**	
Woody shrubs and saplings XMW	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
Non-woody herbs grasses and forbs XMH	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
	Ground cover (,0.5m high)										
Woody shrubs & saplings XGW	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
Non-woody herbs grasses and forbs XGH	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
Barren dirt or duff XGB	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	

Figure 2. Field data form for recording visual riparian estimates. One form for each transect A-K

Following table taken from Kauffman et al. (1999) details the parameter codes and precision metrics of EMAP procedures conducted in Oregon. Parameters in bold type are the most precise. This table is provided for informational purposes only.

Code	Variable name and description	RMSE = σ_{rep}	CV = σ_{rep} / ”(%)	S/N = $\sigma^2_{st(yr)}$ / σ^2_{rep}
XCL	Large diameter tree canopy cover (proportion of riparian)	0.057	38	4.6
XCS	Small diameter tree canopy cover (proportion of riparian)	0.12	55	1.4
XC	**Tree canopy cover (proportion of riparian)**	**0.12**	**33**	**2.4**
XPCAN	**Tree canopy presence (proportion of riparian)**	**0.08**	**8.7**	**10**
XMW	Mid-layer woody vegetation cover (proportion of riparian)	0.12	41	0.9
XMH	Mid-layer herbaceous vegetation cover (proportion of riparian)	0.13	100	0.9
XM	**Mid-layer vegetation cover (proportion of riparian)**	**0.19**	**44**	**0.6**
XPMID	**Mid-layer vegetation presence (proportion of riparian)**	**0.03**	**3.5**	**2.1**
XGW	Ground layer woody vegetation cover (proportion of riparian)	0.17	77	0.1
XGH	Ground layer herbaceous vegetation cover (proportion of riparian)	0.16	40	1.1

XGB	Ground layer barren or duff cover (proportion of riparian)	0.07	47	2.0
XG	Ground layer vegetation cover (proportion of riparian)	0.22	36	0
PCAN_C	Conifer riparian canopy (proportion of riparian)	0.11	58	8.5
PCAN_D	Broadleaf deciduous riparian canopy (proportion of riparian)	0.13	31	7.4
PCAN_M	Mixed conifer-broadleaf canopy (proportion of riparian)	0.16	65	2.9
PMID_C	Conifer riparian mid-layer (proportion of riparian)	0.02	55	37
PMID_D	Broadleaf deciduous riparian mid-layer (proportion of riparian)	0.33	58	0.7
PMID_M	Mixed conifer-broadleaf canopy (proportion of riparian)	0.32	87	0.6

PROCEDURES FOR MEASURING CANOPY COVER

Canopy cover is determined for the stream reach in the treatment and control areas at each of the 11 cross section transects. A convex spherical densitometer (Model B) is used. Six measurements are obtained at each cross section transect at mid-channel

1. At each cross-section transect, stand in the stream at mid-channel and face upstream.
2. Hold the densitometer 0.3 m (1 ft.) above the stream. Hold the densitometer level using the bubble level. Move the densitometer in front of you so that your face is just below the apex of the taped "V".
3. Count the number of grid intersection points within the "V" that are covered by either a tree, a leaf, or a high branch. Record the value (0-17) in the CENUP field of the canopy cover measurement section of the form.
4. Face toward the left bank (left as you face downstream). Repeat steps 2 and 3, recording the value in CENL field of the data form.
5. Repeat steps 2 and 3 facing downstream, and again while facing the right bank (right as you look downstream). Record the values in the CENDWN and CENR fields of the field data form.
6. Repeat steps 2 and 3 again, this time facing the bank while standing first at the left bank, then the right bank. Record the value in the LFT and RGT fields of the data form.
7. Repeat steps 1-6 for each cross-section transect (A-K). Record data for each transect on a separate data form.
8. If for some reason a measure cannot be taken, indicate in the "Flag" column.

Location	1-17	Flag
CENUP		
CENL		
CENDWN		
CENR		
LFT		
RGT		

Figure 2. Form for recording canopy cover measurements.

Each of the measures taken at the center of the stream are summed for all 11 transects and converted to a percentage based upon a maximum score of 17 per transect. The results are then averaged to produce a mean % canopy density at mid-stream (XCDENMID).

Each of the measures taken at the banks of the stream are summed for all 11 transects and converted to a percentage based upon a maximum score of 17 per transect. The results are then averaged to produce a mean % canopy density at the stream bank (XCDENBK).

Each of the measures are totaled and averaged to produce the following table of riparian vegetative cover.

Table 1. The shaded composite variables are considered the most important in terms of their precision and are the ones that will be used to determine effectiveness of riparian plantings. RMSE = σ_{rep} is the root mean square error. The lower the value, the more precise the measurement. CV σ_{rep} / ”(%) is the coefficient of variation. The lower the number, the more precise the measurement. S/N = $\sigma^2_{st(yr)}$ / σ^2_{rep} is the signal to noise ratio. The higher the number, the more that metric is able to discern trends or changes in habitat in a single or multiple sites. This table is provided for informational purposes only to show why the indicators were chosen.

Variable	Description	RMSE = σ_{rep}	CV = σ_{rep} / ”(%)	S/N = $\sigma^2_{st(yr)}$ / σ^2_{rep}
XCDENBK	Mean % canopy density at bank (Densitometer reading)	3.9	4.4	17
XC DENMID	**Mean % canopy density mid-stream (Densitometer reading)**	**5.8**	**8.1**	**15**
XCM	Mean riparian canopy + mean mid-layer cover	0.22	33	1.4
XPCM	Riparian canopy and mid-layer presence (proportion of reach)	0.08	9.8	7.9
XPCMG	**3-layer riparian vegetation presence (proportion of reach)**	**0.08**	**9.8**	**8.0**

METHOD FOR MEASURING SUBSTRATE

Protocol taken from: ***Peck et al. (Unpubl.), Table 7-7 modified Wolman pebble count***

PURPOSE

Determining the changes in the percentage of fines and embeddedness within the impact and control areas pre- and post-project in order to determine any significant changes.

EQUIPMENT

Meter stick, surveyor's rod, and metric tape.

SITE SELECTION

The sample reach is laid out according to page 13.

SAMPLE DURATION

Counts should be taken during summer low flow period when turbidity and visibility is normally at its best. This may not be true for glacial streams.

PROCEDURE

Step 1: Substrate size class is estimated for a total of 105 particles taken at 5 equally-spaced points along each of 21 cross sections. Depth is measured and embeddedness estimated for the 55 particles located along the 11 regular transects A through K. Cross sections are defined by laying the surveyor's rod or tape to span the wetted channel. Riparian vegetation are observed 5 m upstream and 5 m downstream from the cross section transect.

Step 2: Fill in the header information on page 1 of a channel riparian cross-section form. Indicate the cross-section transect. At the transect, extend the surveyor's rod across the channel perpendicular to the flow, with the zero end at the left bank (facing downstream). If the channel is too wide for the rod, stretch the metric tape in the same manner.

Step 3: Divide the wetted channel by 4 to locate substrate measurement points on the cross section. In the "DISTLB" fields of the form, record the distances corresponding to **0% (LFT), 25% (LCTR), 50% (CTR), 75% (RCTR), and 100% (RGT)** of the measured wetted width. Record these distances at transects A-K, but just the wetted width at mid-way cross sections.

Step 4: Place your sharp-ended meter stick or calibrated pole at the LFT location (0 m). Measure the depth and record it on the field data form. (Cross section depths are measured only at regular transects A-K, not at the 10 mid-way cross sections.)

Step 5: Pick up the substrate particle that is at the base of the meter stick (unless it is bedrock or boulder), and visually **estimate its particle size**, according to the following table. Classify the particle according to its median diameter (the middle dimension of its length, width, and depth). Record the size class code on the field data form. (Cross section side of form for transects A-K; special entry boxes on Thalweg Profile side of form for mid-way cross-sections.)

Table 2. Substrate classes and size ranges

Code	Score	Size class	Size range (mm)	Description
RS	6	Bedrock (smooth)	>4000	Smooth surface rock bigger than a car
RR	6	Bedrock (rough)	>4000	Rough surface rock bigger than a car
HP	6	Hardpan		Firm, consolidated fine substrate
BL	5	Boulders	>250 to 4000	Basketball to car size
CB	4	Cobbles	>64 to 250	Tennis ball to basketball size
GC	3.5	Gravel (coarse)	>16 to 64	Marble to tennis ball size
GF	2.5	Gravel (fine)	>2 to 16	Ladybug to marble size
SA	2	Sand	>0.06 to 2	Smaller than ladybug size, but visible as particles – gritty between fingers
FN	1	Fines	<0.06	Silt, Clay, Muck, (not gritty between fingers)
WD	0	Wood	Regardless of size	Wood and other organic particles
OT	0	Other	Regardless of size	Concrete, metal, tires, car bodies, etc.

Step 6: Evaluate substrate embeddedness as follows at 11 transects A-K. For particles larger than sand, examine the surface for stains, markings, and algae. Estimate the average percentage embeddedness of particles in the 10 cm circle around the measuring rod. Record this value on the field data form. By definition, sand and fines are embedded 100 percent, bedrock and hardpan are embedded 0 percent.

Step 7: Move successively to the next location along the cross section. Repeat steps 4 through 6 at each location. Repeat steps 1 through 6 at each new cross section transect.

SUBSTRATE CROSS-SECTIONAL INFORMATION					
Project No.		**Date:**		**Transect A-K?**	
	Dist LB XX.XX m	**Depth XXX cm**	**Size Class Code**	**Embed. 0-100%**	**Flag**
Left					
L Ctr					
Ctr					
RCtr					
Right					

SUBSTRATE SIZE CODES		Embed %
RS =	Bedrock Smooth (Larger than a car)	0
RR =	Bedrock (Rough) – (Larger than a car)	0
BL =	Boulder (2250 to 4000 mm) (Basketball to car)	
CB =	Cobble (64 to 250 mm) (Tennis ball to Basketball)	
GC =	Coarse Gravel (16 to 64 mm) (Marble to Tennis ball)	
GF =	Fine Gravel (2 to 16 mm) (Ladybug to Marble)	
SA =	Sand (0.06 to 2 mm) (Gritty up to Ladybug size)	100
FN =	Silt/Clay/Muck (Not Gritty)	100
HP =	Hardpan (Firm, Consolidated Fine Substrate)	0
WD =	Wood (Any Size)	
OT =	Other (Write comment below)	

Flag	**Comments**

Figure 4. Substrate field form

METHOD FOR MEASURING LARGE WOODY DEBRIS (LWD)

Modified Protocol taken from: ***Peck et al. (Unpubl.), pp. 115-117, Table 7-5; Kauffman et al. (1999)***

PURPOSE

These methods are used to tally "large woody debris" (LWD). The tally includes all LWD that are in the baseflow channel (the active channel), or spanning above the active channel. The active, or bankfull, channel is defined as the channel that is filled by moderate-sized flood events that typically occur every one or two years. LWD in the active channel is tallied over the entire length of the reach, including between the channel cross-section transects.

EQUIPMENT

Measuring tape, meter stick, waterproof sampling forms.

SAMPLING DURATION

Counts should be taken during summer low flow in conjunction with other instream measurements such as Thalweg profile.

PROCEDURE

Note: *Tally pieces of LWD within each segment of stream at the same time the Thalweg profile is being determined. Include all pieces whose large end is located within the segment in the tally.*

Step 1: Scan the stream segment between the two cross section transects where Thalweg profile measurements are being made.

Step 2: Tally all LWD pieces within the segment that are at least partially within the bankfull channel. Determine if a piece is LWD (small end diameter 10cm (4 in.); length 1.5 m (5 ft.).

Step 3: For each piece of LWD, determine the class based on the diameter of the large end

- 0.1 m < 0.3 m [4 in < 12 in]
- 0.3 m < 0.6 m [12 in < 24 in]
- 0.6 m < 0.8 m [24 in < 32 in]
- > 0.8 m [> 32 in]

and for the length of the piece

- 1.5 m < 5.0 m [5 ft. < 17 ft.]
- 5.0 m < 15 m [17 ft. < 50 ft.]
- > 15 m [> 50 ft.]

If the piece is not cylindrical, visually estimate what the diameter would be for a piece of wood with circular cross section that would have the same volume.

When estimating length, include only the part of the LWD piece that has a diameter greater than 10 cm (4 in.).

Step 4: Place a tally mark in the appropriate diameter X length class tally box in the "PIECES ALL/PART IN BANKFULL CHANNEL" section of the Thalweg Profile and Woody Debris Form.

Step 5: Tally all LWD pieces within the segment that are not actually within the bankful channel, but are at least partially spanning (bridging) the channel. For each piece, determine the class based upon the diameter of the large end and the class based on the length of the piece.

Step 6: Place a tally mark for each piece in the appropriate diameter X length class tally box in the "PIECES BRIDGE ABOVE BANKFUL CHANNEL" section of the Thalweg Profile and Woody Debris Form.

Step 7: After all pieces within the segment have been tallied, write the total number of pieces for each diameter X length class in the small box at the lower right hand corner of each tally box.

Step 8: Repeat Steps 1 through 7 for the next stream segment, using the Thalweg Profile and Woody Debris Form.

SITE NAME:							**DATE:**				**VISIT:** 1 2	
SITE ID:							**TEAM ID:**					
LARGE WOODY DEBRIS ≥ 10cm small end diameter; 1.5 m length				CHECK IF ALL UNMARKED BOXES ARE ZERO ☐				FLAG				
Diameter Large end	Pieces All/part In Bankfull Channel						Pieces Bridge Above Bankfull channel					
	Length 1.5-5 m		5-`5 m		> 15 m		Length 1.5-5 m		5-`5 m		> 15 m	
0.1 <0.3 m												
0.3 <0.6 m												
0.6 <0.8 m												
>0.8 m												
TOTAL												

Figure 5. Woody debris form taken from EMAP

METHOD FOR CHARACTERIZING STREAM MORPHOLOGY, THALWEG PROFILE

Protocol taken from*: Peck et al. (Unpubl.), Table 7-3; Kauffman et al. (1999)*

PURPOSE

The Thalweg profile can detect changes in the stream morphology associated with habitat restoration projects designed to improve pool-riffle relationships, provide velocity changes and other structure beneficial as hiding and holding habitat for salmonids.

EQUIPMENT

Surveyor's telescoping rod, 50 m measuring tape, laser range finder, camera tripod, 2 - ½ in. diameter PVC pipe, 2-3 m long, meter stick, surveyor tape, Bearing compass, fisherman's vest with lots of pockets, chest waders, appropriate waterproof forms.

SITE SELECTION

The sample reach is laid out according to page 13.

SAMPLING DURATION

Sampling should occur during August-September.

PROCEDURE

The Thalweg Profile is a longitudinal survey of depth, habitat class, presence of soft/small sediment deposits, and off-channel habitat at 100 equally spaced intervals (150 in streams less than 2.5 m wide) along the centerline between the two ends of the sampling reach. "Thalweg" refers to the flow path of the deepest water in a stream channel. Wetted width is measured and substrate size is evaluated at 21 equally spaced cross-sections (at 11 regular Transects A through K plus 10 supplemental cross-sections spaced mid-way between each of these).

Step 1: Determine the interval between measurement stations based on the wetted width used to determine the length of the sampling reach. For widths < 2.5 m, establish stations every 1 m. For widths between 2.5 and 3.5 m, establish stations every 1.5 m. For widths > 3.5 m, establish stations at increments equal to 0.01 times the sampling reach length.

Step 2: Complete the header information on the Thalweg Profile and Woody Debris Form, noting the transect pair (downstream to upstream). Record the interval distance determined in Step 1 in the "INCREMENT" field on the field data form.

NOTE: *If a side channel is present and contains between 16 and 49% of the total flow, establish secondary cross-section transects as necessary. Use separate field data forms to record data for the side channel, designating each secondary transect by checking both "X" and the associated primary transect letter (e.g., XA, XB, etc.). Collect all channel and riparian cross-section measurements from the side channel.*

Step 3: Begin at the downstream end (station "0") of the first transect (Transect "A").

Step 4: Measure the wetted width if you are at station "0", station "5" (if the stream width defining the reach length is 2.5 m), or station "7" (if the stream width defining the reach length is < 2.5 m). Wetted

width is measured across and over mid-channel bars and boulders. Record the width on the field data form to the nearest 0.1 m for widths up to about 3 meters, and to the nearest 5% for widths > 3 m. This is 0.2 m for widths of 4 to 6 m, 0.3 m for widths of 7 to 8 m, and 0.5 m for widths of 9 or 10 m, and so on. For dry and intermittent streams, where no water is in the channel, record zero for wetted width.

NOTE: *If a mid-channel bar is present at a station where wetted width is measured, measure the bar width and record it on the field data form.*

Step 5: At station "5" or "7" (see above) classify the substrate particle size at the tip of your depth measuring rod at the left wetted margin and at positions 25%, 50%, 75%, and 100% of the distance across the wetted width of the stream. This procedure is identical to the substrate size evaluation procedure described for regular channel cross-sections A through K, except that for these mid-way supplemental cross-sections, substrate size is entered on the Thalweg Profile side of the field form.

Step 6: At each Thalweg Profile station, use a meter ruler or a calibrated pole or rod to locate the deepest point (the "thalweg"), which may not always be located at mid-channel. Measure the thalweg depth to the nearest cm, and record it on the Thalweg Profile form. Read the depth on the side of the ruler, rod, or pole to avoid inaccuracies due to the wave formed by the rod in moving water.

NOTE: *For dry and intermittent streams where no water is in the channel, record zeros for depth.*

NOTE: *At stations where the thalweg is too deep to measure directly, stand in shallower water and extend the surveyor's rod, calibrated rod, or pole at an angle to reach the thalweg. Determine the rod angle by resting the laser range finder on the upper surface of the rod and reading the angle on the external scale of the laser range finder. Leave the depth reading for the station blank, and record a "U" flag. Record the water level on the rod and the rod angle in the comments section of the field data form. For even deeper depths, it is possible to use the same procedure with a taut string as the measuring device. Tie a weight to one end of a length of string or fishing line and then toss the weight into the deepest channel location. Draw the string up tight and measure the length of the line that is under water. Measure the string angle with the laser range finder exactly as done for the surveyor's rod.*

Step 7: At the point where the thalweg depth is determined, observe whether unconsolidated, loose ("soft") deposits of small diameter (<16mm), sediments are present directly beneath your ruler, rod, or pole. Soft/small sediments are defined here as fine gravel, sand, silt, clay or muck readily apparent by "feeling" the bottom with the staff. Record presence or absence in the "SOFT/SMALL SEDIMENT" field on the field data form. Note: A thin coating of fine sediment or silty algae coating the surface of cobbles should not be considered soft/small sediment for this assessment. However, fine sediment coatings should be identified in the comments section of the field form when determining substrate size and type.

Step 8: Determine the channel unit code and pool forming element codes for the station. Record these on the field data form using the standard codes provided. For dry and intermittent streams where no water is in the channel, record habitat type as dry channel (DR).

Step 9: If the station cross-section intersects a mid-channel bar, indicate the presence of the bar in the "BAR WIDTH" field on the field data form.

Step 10: Record the presence or absence of a side channel at the station's cross-section in the "SIDE CHANNEL" field on the field data form.

Step 11: Record the presence or absence of quiescent off-channel aquatic habitats, including sloughs, alcoves and backwater pools in the "BACKWATER" column of the field form.

Step 12: Proceed upstream to the next station and repeat Steps 4 through 11.

Step 13: Repeat Steps 4 through 12 until you reach the next transect. At this point, complete Channel/Riparian measurements at the new transect (Section 7.5). Then prepare a new Thalweg Profile and Woody Debris Form and repeat Steps 2 through 12 for each of the reach segments, until you reach the upstream end of the sampling reach (Transect "K").

THALWEG PROFILE FORM										
SITE NAME:					DATE:		VISIT: 1 2			
SITE ID:					TEAM ID:					
TRANSECT (X) A-B B-C C-D D-E E-F F-G G-H H-I I-J J-K										
THALWEG PROFILE							Increment (m) →			
Station	Thalweg Depth cm (XXX)	Wetted Width (XX.X)	X	(XX.X)	Soft/Small sediment (X for yes)	Channel Unit Code	Pool Form Code	Side Channel (X for yes)	Flag	Comments
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
TOTAL										
MEAN										
VAR										
SE										

Figure 6. Thalweg profile form taken from EMAP

METHOD FOR MEASURING RESIDUAL DEPTH

Protocol taken from: ***Peck et al. (Unpubl.), Table 7-6; Kauffman et al. (1999)***

PURPOSE

Using the following methods, the water surface slope and bearing can be determined. These measures can be used to calculate residual pool depth. Residual pool volume is the amount of water that would remain in the pools if there were not flow and the pools were impermeable basins. The intent of measuring this parameter is to show the changes in cross-sectional stream complexity typified by pools and riffles.

Slope and bearing are measured using two people by back-sighting downstream between transects.

EQUIPMENT

Surveyor's telescoping stadia rod, 50 m measuring tape, laser range finder, camera tripod, 2 – ½ in diameter PVC pipe, 2-3 m long, surveyor flagging tape, Bearing compass, fisherman's vest with lots of pockets, chest waders, appropriate waterproof forms.

PROCEDURE

Step 1: Stand in the center of the channel at the downstream cross-section transect. Determine if you can see the center of the channel at the next cross-section transect upstream without sighting across land (i.e. do not short circuit a meander bend). If not, you will have to take supplementary slope and bearing measurements.

Step 2: Set up a tripod in shallow water or have one person hold a **stadia rod** at the downstream cross-section transect (or at a supplemental point). Standing tall in a position with your feet as near as possible to the water surface elevation, set the **tripod** extension and mark it with a piece of **flagging tape** at your eye level. Remember the depth of water in which you are standing when you adjust the flagging to eye level.

Step 3: Walk upstream to the next cross-section transect. Find a place to stand at the upstream transect that is at the same depth as where you stood at the downstream transect when you set up the eye level flagging.

Step 4: With the **laser range finder**, site back downstream on your flagging at the downstream transect. Read and record the percent slope in the "MAIN" section on the **Slope and Bearing Form**. Record the "PROPORTION" as 100%.

Step 5: Stand in the middle of the channel at upstream transect, and site back with your **compass** to the middle of the channel at the downstream transect. Record the bearing (degrees) in the "MAIN" section of the Slope and Bearing Form.

Step 6: Retrieve the tripod from the downstream cross-section station and setup at the next upstream transect as described in Step 2.

Step 7: When you get to each new cross-section transect, back sight on the previous transect. Repeat steps 2 through 6 above.

Residual Pools

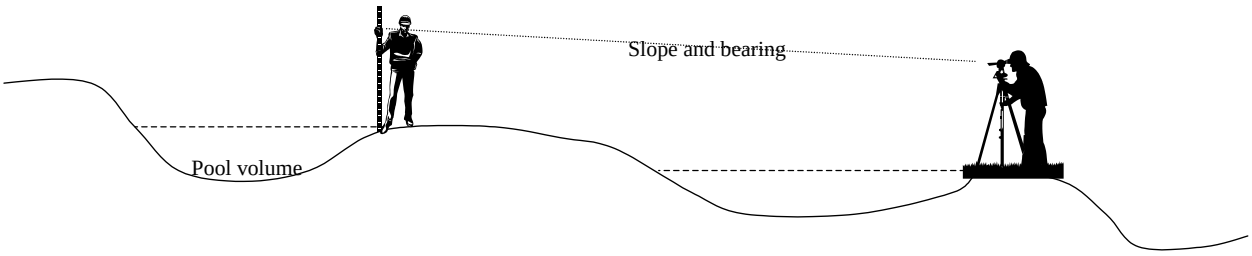

Figure 7. Residual Pools

Project No:		Con/Impact		Sample Year			Date:		Stream	
TRANSECT	MAIN			1ST SUPPLEMENTAL			2ND SUPPLEMENTAL			FLAG
	SLOPE XX.X %	BEARING 0-359	PROPOR-TION %	SLOPE XX.X %	BEARING 0-359	PROPOR-TION %	SLOPE XX.X %	BEARING 0-359	PROPOR-TION %	
A > B										
B > C										
C > D										
D > E										
E > F										
F > G										
G > H										
H > I										
I > J										
J > K										

FLAG	COMMENTS

Figure 8. Residual depth form taken from EMAP

METHOD FOR MEASURING ACTIVELY ERODING STREAMBANKS

Protocol taken from: ***Moore et al. (1998)***

PURPOSE

The protocol will allow us to determine if the stream banks within the habitat restoration area have improved and thereby reduced siltation and erosion by reducing the percentage of the streambank that is actively eroding.

EQUIPMENT

Appropriate waterproof sampling form, waders or hip boots.

SITE SELECTION

The sample reach is laid out according to page 13.

PROCEDURE

Estimate the percent of the lineal distance of both sides of the transect that is actively eroding at the active channel height. Active erosion is defined as actively, recently eroding or collapsing banks and may have the following characteristics: exposed soils and inorganic material, evidence of tension cracks, active sloughing, or superficial vegetation that does not contribute to bank stability.

Transect	Left Bank	Right Bank
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		
K		
Total (sum left & right bank)		
Mean Percent erosion (total/22)		
Variance		

Figure 9. Bank erosion form. Percent erosion.

METHOD FOR DETECTING FISH SPECIES ASSEMBLAGES USING BACKPACK ELECTROFISHING OR SNORKELING

Modified Protocol taken from: ***Peck et al. (Unpubl.) Table 12-2 and 12-5.***

PURPOSE

This protocol is designed to calculate an Index of Biological Integrity (IBI) for fish species found within the sampled study reach. The health of a stream in terms of fish can be determined by species composition and age class structures. The IBI will be used to compare the changes, if any, in the fish population structure over time.

EQUIPMENT

Use a backpack electrofisher consisting of an anode and cathode pole and capable of producing adjustable pulsed D.C. voltage up to 300 volts and an amp meter allowing adjustable amperage up to 1.5 amps. Determine that all team members are wearing waders and gloves, polarized sunglasses, and capture nets. The electrofisher should have automatic current switches in case the operator falls. The electrofisher should be equipped with an audio indicator when the unit is turned on and warning devices when voltage or current exceeds 300 volts or 1.5 amps. Appropriate capture nets and buckets should be available to capture and hold fish, watch or stopwatch, sample bottles, 10% formalin, labels, digital camera, appropriate field forms.

Persons conducting snorkel counts should be equipped with dry suits or wet suits, masks, snorkels, and rubber soled boots. Additional equipment such as hand counters and underwater white boards are helpful for enumerating fish.

SITE SELECTION

The sample reach is laid out according to page 13.

SAMPLING DURATION

Sampling for fish species should occur during the low flow period in late summer.

ELECTROFISHING SAMPLING PROCEDURES

Step 1: Be sure that all collectors' permits and ESA clearances have been obtained before proceeding.

Step 2: Allocate the fishing time between all sampled A-K transects within the stream reaches based on stream size and complexity.

Step 3: If conductivity, turbidity, or depth precludes backpack electrofishing, sample by snorkeling, seining, or otherwise, do not sample.

Step 4: Once the settings on the electrofisher have been set properly, begin sampling the reach and fish in an upstream direction. Sample available cut-bank and snag habitat as well. Be sure that deep, shallow, fast, slow, complex, and simple habitats are all sampled.

Step 5: Continue upstream until the next transect is reached. Process fish and change water after each transect to reduce mortality and track sampling effort.

Step 6: Complete Fish Index Form.

Step 7: Repeat steps 2-6 until transect J-K is finished.

Step 8: Determine the species.

SNORKELING SAMPLING PROCEDURES

Step 1: Begin at the downstream boundary of the control or impact study reach, as laid out under identified methods, and proceed upstream through the pools and riffles. In many smaller streams the riffle areas will be too shallow to snorkel and will contain mostly smaller young of the year trout species.

Step 2: A two person snorkeling crew can conduct snorkel surveys in wadeable stream control and impact study reaches. In areas where the stream is not wadeable, up to four snorkelers may be needed. In wadeable stream reaches, one crew member should snorkel each pool-riffle area while the other crew member records the counts as they are given by the snorkeler. In non-wadeable areas, crew members should snorkel side by side and sum their individual counts. Each snorkeler counts the fish to the immediate front and to the sides opposite the other snorkeler or as designated by the team leader to avoid duplication of counts.

Step 3: In all wadeable and most non-wadeable stream reaches, snorkeling should involve only a single pass through each pool-riffle area.

Step 4: Counts of the number of juvenile salmonids should be recorded for each pool-riffle area. Summer estimates of juvenile salmonids should be limited to age 1+ fish for all species except chinook salmon (>50mm).

Step 5: After snorkeling, the underwater visibility of each study reach is ranked on a scale of 0 to 3 where 0 = not snorkelable due to an extremely high amount of hiding cover or zero water visibility; 1 = high amount of hiding cover or poor water clarity; 2 = moderate amount of hiding cover or moderate water clarity, neither of which were thought to impede accurate fish counts; and 3 = little hiding cover and good water clarity.

Step 6: Only pool-riffles with a visibility rank of two or three should be used in data analysis. The proportion of trout estimated by sample electrofishing that were cutthroat and steelhead should be used to reclassify unknown trout as underwater determination of species is often impossible.

Step 7: Determine pool-riffle area for each reach utilized in Steps 1-6 by using the modified Methods for Characterizing Stream Morphology on page 22.

Step 8: For each study reach, the number of fish/m2 of pool-riffle habitat can be calculated for chinook, coho, steelhead, and cutthroat by averaging the density estimates for each pool-riffle. A study reach density will be obtained for each species of interest by averaging the individual pool-riffle densities.

Step 9: Consult Thurow (1994) for additional information.

	FISH IBI COLLECTION FORM												
	Stream Name:					**Collector:**							
	Project #:	**Date:**											
	Worksite:					**Page**		of					
	Common Name	**Tally**	**Total Count**	**Min length**	**Max length**	**Anomaly count**	**Mort count**	**Flag**	**A B**	**C D**	**E F**	**G H**	**I J**
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

	FISH AGE CLASS FREQUENCY DISTRIBUTION							
	Common Name	**Length (mm)**	**Common Name**	**Length (mm)**	**Common Name**	**Length (mm)**		

Figure 10. Fish IBI collection form taken from Mebane (2003)

FISH ID AND TALLY PROCEDURE

Step 1: Complete all header information accurately and completely. If no fish were collected, write "NONE COLLECTED" in the species column.

Step 2: Identify and process each individual completely, ideally handling it only once. Record the common name on the field form. If a species is unknown, assign it as "UNKNOWN" followed by its family name if known. Note the transect where each species is collected.

Step 3: Process species listed as threatened and endangered first and return individuals immediately to the stream.

Step 4: Keep voucher specimens of unknown species for future identification. Using a digital camera photograph all other species as a voucher.

Step 5: Tally the number of individuals of each species collected in the "TALLY" box and record the total number in the TOTAL COUNT field.

Step 6: Measure the total body length of the largest and smallest individuals to provide a size range for the species. For salmon, trout, char, and sculpins measure all specimens and record in the "AGE CLASS FREQUENCY DISTRIBUTION" part of the field form.

Step 7: Examine each individual for external anomalies and tally those observed. Readily identified anomalies include missing organs (eye, fin), skeletal deformities, shortened operculum, eroded fins, irregular fin rays or scales, tumors, lesions, etc. After all species have been processed, record the total number of individuals with anomalies in the "ANOMALY COUNT" area of the form.

Step 8: Record the total number of mortalities due to electrofishing or handling on the form.

Step 9: Follow the appropriate procedure to prepare voucher specimens. Release all remaining individuals.

Step 10: For any line with a fish name, ensure that all spaces on that line are filled in with a number, even if it is zero.

Step 11: Repeat steps 2-10 for all other species.

FISH IBI CALCULATION PROCEDURES

Step 1: Calculate the total number of fish species present and enter the number into the Fish IBI Worksheet. Determine the score from the formulas provided below from Mebane et al. (2003) and enter it on the appropriate line.

Step 2: Repeat for each of the parameters measured.

Table 3. Fish IBI calculation table

IBI Parameter	*Total*	*IBI Score*
# native CW species		
% of sculpin individuals		
% of sensitive native individuals		
% of coldwater individuals		
% of tolerant individuals		
# of alien species		
% of common carp individuals		
CPUE of coldwater individuals		
% of individuals with anomalies		
# of selected salmonid age classes		
Total IBI Score		

SCORING CHARTS AND FORMULAS

Percent Coldwater Individuals
The score for percent coldwater species is calculated from the formula **y = 0.0143x** where y is the score and x is the percent coldwater individuals calculated from the field data. Coldwater species are those species normally occupying coldwater and will include non-native trouts, chars, and other species.

Percent Sensitive Native Individuals
The score for percent sensitive native individuals is calculated from the formula **$y = 0.014 + 0.039x – 5.38E – 4x^2 + 2.47E – 6x^3$** where y is the score, x is the percent sensitive native individuals, and E is the natural log.

Percent Individuals with Anomalies
The score for percent individuals with anomalies is calculated from the formula **$y = e^{-0.69x}$** where y is the score, x is the percent individuals with anomalies expressed as a whole number not a decimal, and e is the natural log.

Number of Coldwater Native Species
The score for number of coldwater species is calculated from the formula **y = 0.33x** where y is the score and x is the percent coldwater individuals calculated from the field data. Coldwater species are those species normally occupying coldwater and will not include non-native trouts, chars, and other species.

Number of Selected Salmonid Age Classes

Ages	0	1	2	3	>3
Score	0	0.1	0.5	0.875	1

Percent Tolerant Individuals
The score for the percent of tolerant individuals is calculated from the formula

$Y = (0.987 – 0.0065)/ 1 + (x/40.3)^{7.23} + 0.0065$

Where y is the score and x is the percent tolerant individuals. Tolerant individuals are the proportion of fish that thrive in or tolerate poor quality physical and chemical habitat

Number of Alien Species

Number	0	1	2	3	>3
Score	1	0.5	0.25	0.0625	0

Percent Carp
The score for percent carp is calculated from the formula $\mathbf{y = e^{-0.69x}}$ where y is the score, x is the percent carp expressed as a whole number not a decimal, and e is the natural log.

Catch Per Unit Effort (CPUE) of Coldwater Individuals
To calculate the score for the number of coldwater individuals captured per minute, the formula $\mathbf{Y = 0.0225 + 0.642x - 0.155x^2 + 0.0147x^3}$ where y is the score and x is the CPUE.

PROCEDURES FOR PREPARING FISH VOUCHER SPECIMENS

Protocol taken from: *Peck et al. Table 12-6*

Step 1: Determine the voucher class of a species and the number of specimens to include in the voucher sample based upon the following guidelines. Process **Class 1 species first**.

Class 1 - State or federally listed species. Photograph and release immediately. Photographs should include (1) a card with the stream ID and (2) an object of known length with the specimen. If specimens have died, proceed to Step 2 and include them in the voucher sample. Flag the species with an "Fn" on the Collection Form and note it is a listed species in the comments section of the form.

Class 2 – Large, easily identified species or adults that are difficult to identify or species that are uncommon in that region. Preserve 1-2 small (<150mm total length) adult individuals per site plus 2-5 juveniles. If only large adults are collected, reserve smallest individuals until voucher procedure is complete and preserve only if space is available. Individuals with a total length > 160mm should be slit on the lower abdomen of the right side before placing them in the container. Photograph if considered too large for the jar or place in a bag on ice for freezing.

Class 3 - Small to moderate size fish or difficult to identify species (e.g. lampreys, juvenile salmonids, minnows, sculpins). Preserve up to 20 adults and juveniles (several per transect). If fewer than 20 individuals are collected, voucher them all.

Step 2: Anesthetize voucher specimens in a bucket with two carbon dioxide tablets and a small volume of water, then transfer them to a nylon mesh bag. Tally, then record the number of individuals included in the voucher sample in the "VOUCHERED COUNT" field for the species on the Collection form.

Step 3: Select a "FISH BAG" tag with the same ID number as the voucher sample jar. Record the tag number in the "TAG NO" field on the corresponding line for the species on the Collection Form. Place the tag into the mesh bag and seal. **This bagging, tagging, and recording is crucial, as it enables us to estimate species proportionate abundances in the assemblages even when one suspected species turns out to be multiple species.**

Step 4: Immediately place the bag into a container large enough to hold the voucher specimens loosely and half filled with 10% formalin. **Use additional jars if necessary to avoid close packing and bending of voucher specimens**.

Step 5: Repeat steps 1 through 4 for all species collected.

METHOD FOR DETERMINING MACRO-INVERTEBRATE SPECIES ASSEMBLAGES

PURPOSE

The health of a stream can be determined from the species of macro-invertebrates present. Some species of aquatic insects are very sensitive to water quality problems and others are affected by sedimentation or temperature. The purpose of this protocol is to provide for a standard method of measuring changes in the macro-invertebrate assemblages of streams acquired by the SRFB. A macro-invertebrate index (MMI) is calculated based upon previous studies and used to compare results against future measures at the same site and other sites.

EQUIPMENT

Modified kick net (D-Frame with 500 micro meter mesh) and 4 ft handle (Wildco # 425-C50), stop watch, plastic buckets (8-10 qt), sieve with 500 micro meter mesh openings. Forceps, wash bottle, spatula, spoon or scoop, funnel with large bore spout, sample jars, ethanol (95%), rubber gloves, cooler, composite benthic sample labels with preprinted ID numbers (barcodes), blank labels on waterproof paper for inside of jars, sample collection form, clear packing tape for sealing jars, plastic electrical tape, scissors, appropriate field forms.

SITE SELECTION

The sample reaches should be laid out according to on page 13.

SAMPLING DURATION

Sampling should occur at the same time that other samples are taken from the stream reach for fish assemblages and for habitat measures.

PROCEDURE TO COLLECT KICK NET SAMPLES

Protocol modified from: ***Peck et al. (2001) Table 11-3 and 11-4 Targeted Riffle Sample***

Step 1: Before sampling, survey the stream reach to estimate the total number (and area) of riffle habitat units contained in the defined stream reach. To be considered as a unit the area must be greater than 1 square foot.

A. Do not sample poorly represented habitats. If the reach contains less than 8 ft^2 of riffle macrohabitat, then do not collect a targeted riffle sample.
B. If the reach contains more than one distinct riffle macrohabitat unit but less than eight, allocate the eight sampling points among the units so as to spread the effort throughout the reach as much as possible. You may need to collect more than one kick sample from a given riffle unit.
C. If the number of riffle macrohabitat units is greater than eight, skip one or more habitat units at random as you work upstream, again attempting to spread the sampling points throughout the reach.

Step 2: Begin sampling at the most downstream riffle unit, and sample units as they are encountered to minimize instream disturbance.

Step 3: At each unit exclude "margin" habitats by constraining the potential sampling area. Margin habitats are edges, along the channel margins or upstream or downstream edges of the riffle macrohabitat unit. Define a core area for each riffle unit as the central portion, visually estimating a

"buffer" strip circumscribing the identified unit. In some cases, the macrohabitat unit may be so small that it will not be feasible to define a core area and avoid and edge.

Step 4: Visually lay out the core area of the unit sampled into 9 equal quadrants (i.e 3X3 grid). For each macrohabitat type, select a quadrant for sampling at random from the following list of locations (right and left are determined as you look downstream)

Lower right quadrant
Lower center quadrant
Lower left quadrant
Right center quadrant
Center quadrant
Left center quadrant
Upper right quadrant
Upper center quadrant
Upper left quadrant

Step 5: Beginning at the most downstream riffle unit within the sampling reach, locate the sampling point within the microhabitat as described in Steps 3 and 4.

Step 6: Attach the 4 ft handle to the kick net. Make sure that the handle is on tight or the net may become twisted in a strong current, causing the loss of part of the sample.

Step 7: With the net opening facing upstream, position the net quickly and securely on the stream bottom to eliminate gaps under the frame. Avoid large rocks that prevent the sampler from sealing properly on the stream bottom.

Step 8: Holding the net in position on the substrate, visually define a rectangular quadrant that is one net width wide and one net width long upstream of the net opening. The area within this quadrant is 0.09 m^2 (1 $ft.^2$). Alternatively place a wire frame of the correct dimensions in front of the net to help delineate the quadrant to be sampled.

Step 9: Hold the net in place with your knees. Check the quadrant for heavy organisms, such as mussels and snails. Remove these organisms from the substrate by hand and place them into the net. Pick up any loose rocks or other larger substrate particles in the quadrant. Use your hands or a small scrub brush to dislodge organisms so that they are washed into the net. Scrub all rocks that are golf ball sized or larger and which are over halfway into the quadrant. Large rocks that are less than halfway into the quadrant are pushed aside. After scrubbing, place the substrate particles outside the quadrant.

Step 10: Keep holding the sampler securely in position. Start at the upstream end of the quadrant, vigorously kick the remaining finer substrate within the quadrant for 30 seconds (use a stopwatch).

Step 11: Pull the net out of the water. Immerse the net in the stream several times to remove fine sediments and to concentrate organisms at the end of the net. Avoid having any water or material enter the mouth of the net during this operation.

Step 12: Invert the net into a plastic bucket marked "TARGETED RIFFLE" and transfer the sample. Inspect the net for any residual organisms clinging to the net and deposit them into the bucket as well. Use forceps if necessary to remove organisms from the net. Carefully inspect any large objects (such as rocks, sticks, and leaves) in the bucket and wash any organisms found off the objects and into the bucket before discarding the object. Remove as much detritus as possible without loosing organisms.

Step 13: Record the nearest transect location in the box for the sample on the Sample Collection Form. Place an "X" in the appropriate substrate type box for the transect on the Collection Form.

Fine sand:	Not gritty (silt/clay/muck < 0.06mm diam.) to gritty, up to ladybug sized (2 mm diam.)
Gravel:	Fine to coarse gravel (ladybug to tennis ball sized; 2mm to 64 mm diam.)
Coarse:	Cobble to boulder (tennis ball to car sized; 64mm to 4000 mm).
Other:	Bedrock (larger than car sized; > 4000 mm), hardpan (firm, consolidated fine substrate, wood of any size, aquatic vegetation, etc.). Note type of "Other" substrate in comments on field form.

Step 14: Thoroughly rinse the net before proceeding to the next sampling location.

Step 15: Repeat steps 1-14 at subsequent riffle sampling points until 8 kick samples have been collected and placed in the "TARGETED RIFFLE" BUCKET.

PROCEDURE FOR PREPARING COMPOSITE SAMPLES FOR IDENTIFICATION

Protocol modified from: *Peck et al. (2001), Table 11-5*

Step 1: Pour the entire contents of the "TARGETED RIFFLE" bucket through a sieve with 500 micro-meter mesh. Remove any large objects and wash any clinging organisms back into the sieve before discarding.

Step 2: Using a wash bottle filled with stream water, rinse all organisms from the bucket into the sieve. This is the composite reach-wide sample for the site.

Step 3: Estimate the total volume of the sample in the sieve and determine how large a jar will be needed for the sample. Avoid using more than one jar for each composite sample.

Step 4: Fill in a "TARGETED RIFFLE" sample label with the stream ID and date of collection. Attach the completed label to the jar and cover it with a strip of clear packing tape.

Step 5: Wash the contents of the sieve to one side by gently agitating the sieve in the water. Wash the sample into the jar, using as little water from the wash bottle as possible. Use a large bore funnel if necessary. If the jar is too full, pour off some water through the sieve until the jar is not more than ¼ full, or use a second jar if a larger one is not available. Carefully examine the sieve for any remaining organisms and use forceps to place them into the sample jar.

Step 6: Place a waterproof label with the following information inside each jar:

- Project number
- Worksite description
- Type of sampler and mesh size used
- Name of stream
- Date of collection
- Collector's name
- Number of transects sampled composited

Step 7: Completely fill the jar with the 96% ethanol (no headspace) so that the final concentration of ethanol is between 75 and 90%. It is very important that sufficient ethanol be used, or the organisms will not be properly preserved.

Step 8: Replace the cap on each jar. Slowly tip the jar to a horizontal position, then gently rotate the jar to mix the preservative. Do not invert or shake the jar. After mixing, seal each jar with plastic electrical tape.

Step 9: Store labeled composite samples in a container until transport to the laboratory.

MULTI-METRIC INDEX DEVELOPMENT

Protocol taken from: *Wiseman (2003), Tables 1, 8, and 9*

Step 1: Obtain results from laboratory analysis of species present in the REACHWIDE composite sample and their relative abundance.

Step 2: Determine the following metrics from the laboratory sample:

- Percent of the family Chironomidae of the total sample count
- Percent of the Orders Ephemeroptera, Plecoptera, and Trichoptera of the total sample count
- Percent of the Order Ephemeroptera of the total sample count
- Hilsenhoff Biotic Index (HBI) which is calculated by multiplying the number of individuals of each species by its assigned tolerance value, summing these products, and dividing by the total number of individuals
- Total number of taxa
- Number of highly intolerant taxa, as defined by Wiseman (1998)
- Percent of clinger taxa of the total sample count
- Number of clinger taxa
- Number of intolerant taxa with a tolerance value less than 3 (TV3)
- Percent of the tolerant taxa of the total sample count with a tolerance value greater than 7 (TV7)
- Percent of the top 3 abundant taxa of the total sample count
- Percent of the filter taxa of the total sample count
- Percent of the predator taxa of the total sample count
- Percent of the scraper taxa of the total sample count
- Number of long-lived taxa

Step 3: Score each indicator based upon the following tables taken from Wiseman (2003).

Table 4. Scoring criteria for Puget lowland area MMI.

		Scoring Criteria		
Category	**Metric**	**1**	**3**	**5**
Richness	Total richness	<24	24-33	>33
Richness	Ephemeroptera richness	<4	4-6	>6
Richness	Plecoptera richness	<3	3-5	>5
Richness	Trichoptera richness	<4	4-6	>6
Tolerance	Intolerant richness (bi)	<2	2	>2
Tolerance	% tolerant (TV7)	>19	11-19	<11
Tolerance	% top 3 abundant	>70	54-70	<54
Trophic/habitat	% predators	<11	11-19	>19
Trophic/habitat	% clingers	<26	26-47	>47
Voltinism	Long lived richness	<3	3-5	>5

Table 5. Scoring criteria for Cascade MMI.

		Scoring Criteria		
Category	**Metric**	**1**	**3**	**5**
Composition	% Ephemeroptera	<35	35-57	>57
Richness	Total richness	<37	37-52	>52
Richness	Plecoptera richness	<5	5-9	>9
Richness	Trichoptera richness	<9	9-12	>12
Richness	Clinger richness	<12	12-16	>16
Tolerance	Intolerant richness (bi)	<6	6-9	>9
Tolerance	% tolerant (bi)	>23	12-23	<12
Tolerance	HBI	>3.8	2.8-3.8	<2.8
Trophic/habitat	% filterers	>28	15-28	<15
Trophic/habitat	% clingers	<36	36-54	>54

Scoring criteria for eastern Washington are under development by the Department of Ecology.

METHOD FOR DETERMINING UPLAND VEGETATION SPECIES DIVERSITY AND DENSITIES

Protocol provided by Joseph Arnett of Tetra Tech FW, Inc. with some procedures taken from: ***USDI National Park Service Fire Monitoring Handbook (2003) Chapter 4 Monitoring Program Design Table 3, Table 4 and Figures 9-14; and Chapter 5 Vegetation Monitoring Protocols Tables 5-10 and Figures 15-20.***

PURPOSE

Many SRFB acquired lands contain significant areas of upland habitat that either were acquired in fee title or by easement to protect the downslope portion of the salmon bearing stream, or they were part of a parcel of land having significant riparian and instream habitat and the uplands were acquired as part of the parcel requirements. In either event, health of upland habitat should be maintained or improved where stream and riparian protection is a high priority. Upland areas contribute to erosion, landslides, high runoff and high stream temperatures. These protocols are intended to track forest cover, brush and grasslands species diversity, and density as a measure of their health and changes since the base year when purchased.

EQUIPMENT

Topographic maps, ESRI Arc View or ArcMap software with appropriate laptop or desktop computer, aerial orthophotographs, digital camera, compass, hand held GPS unit, engineering flagging tape, 2 ft. rebar stakes, hammer, blue and orange forestry marking paint, plot identification tags, wire, clipboard and pencils, standard plant press, plastic bags for plant samples, plant identification guides, 50 meter tape, 10 meter DBH tape, aluminum nails, small gardening trowel, tally meter, and appropriate waterproof field forms.

SITE SELECTION

Within acquisition project areas, plot locations in upland areas will be randomly located on transects established within vegetation polygons that have been delineated on orthophotos in GIS format. While plots will be randomly located, transects will be positioned to facilitate their relocation and to sample the range of vegetation present on the site. Data will be collected in these plots in accordance with the procedures described below.

SAMPLING DURATION

Sampling should occur during the late spring or summer when the majority of flowers are in bloom and when it is easiest to identify grasses and other kinds of ground cover. This time period may vary slightly from year to year depending on climatic factors. Sampling in succeeding years should occur at approximately the same stage of vegetation development.

PROCEDURE FOR DELINEATING VEGETATION POLYGONS

Step 1: Obtain orthophotographs of all acquisitions to be sampled.

Step 2: For each acquisition, delineate major vegetation polygons by visual inspection of the orthophotos in GIS format (Arc View or ArcMap). The level of resolution of this delineation depends on the type of vegetation, but would, at a minimum, distinguish between forested, shrub steppe, and grassland communities, and within these vegetation types distinguish between stands that are visually distinct due to differences in stand age, level of disturbance, and dominant species. Forested polygons would not generally be expected to be smaller than five acres; herbaceous polygons might be much smaller, especially in emergent wetlands where boundaries between vegetation types may be

distinguished at a much finer scale. Vegetation polygons in emergent wetlands are often distinct and based on dominance of a single species.

PROCEDURE FOR FIELD EVALUATING VEGETATION POLYGONS

Note: This procedure would be applied to assessment of acquisitions for wildlife habitat, but would not be applied to salmon habitat acquisition projects.

Protocol taken from: *Washington Natural Heritage Program*

Step 1: During the field survey, verify the boundaries of the vegetation polygons as delineated in GIS.

Step 2: Classify and assess the vegetation within the polygon using the field data form. Plant associations will be based on the best available classifications, including those developed by the Washington Natural Heritage Program or National Forests. If existing classifications are not applicable, the vegetation will be characterized by the dominant species in each vegetation layer. The source of the classification will be included in the data.

Step 3: During field examination, each polygon will be examined for its vegetation history, based on conditions in the field and augmented with information obtained from local land managers.

Step 4: The following information will be recorded on Polygon Vegetation Data Sheets (Figure 11) for each of the identified polygons:

- Survey intensity
- Total percent cover of vascular plants, mosses, and lichens.
- Canopy cover of trees, shrubs, graminoids, forbs, and exotics, by cover class.
- The most abundant species in each life form category.
- Diameter at breast height (DBH), species, length of core and number of rings counted for cored trees.
- Soil surface cover of rock, gravel, bare ground, mosses, and lichens, and litter, by cover class.
- Land use, including probable stand age, agriculture, livestock, development, wildlife use, and recreation type and severity.
- All plant associations encountered in each polygon, with list sources of plant associations.
- Condition rank of plant association.
- Estimation of percent of each plant association in each polygon.
- Pattern of distribution of each plant association in the polygon.
- Brief comments about each plant association.
- Remarks about the polygon as a whole, including information on the presence of noxious weeds, incidental observations of rare plants, wetlands, or other sensitive or unique features, and preliminary management recommendations.

VEGETATION POLYGON DATA FORM				
SITE:			**SURVEYOR'S NAME(S):**	
POLYGON #	**DATE:**		**Survey Intensity:**	**photo roll/#:**
	% cover	species	species	species
TOTAL VEGETATION				
TREES total				
emergent				
main canopy				
subcanopy				
SHRUBS total				
over 1.5' tall				
less than 1.5' tall				
GRAMINOIDS total				
perennial				
FORBS total				
perennial				
annual				
EXOTICS total				
perennial				
annual				
SOIL SURFACE				
rock outcrop				
gravel/erosion pavement				
bareground/soil				
mosses and lichens				
litter				
LAND USE				
Logging				
Stand Age				
Agriculture				
Livestock				
Development				
Wildlife				
Recreation Severity				
Recreation Type				
Hydrology				
PLANT ASSOCIATION	**Rank**	**% of polygon**	**pattern**	**comments**
Remarks				

Figure 11. Vegetation Polygon Data Form (Source: Washington Natural Heritage Program)

Step 5: Subjective ecological conditions will be assigned to plant associations based on the following table:

Table 6. Ecological Conditions Rating Table (Source: Washington Natural Heritage Program)

Rating	Description
A Excellent	Plant association is pristine, appears to have experienced little or no present or past disturbance by post-industrial humans, is a large stand, or exhibits exceptional species diversity.
B Good	Plant association is in good to very good condition. Species composition and diversity are within the range expected for the type.
C Moderate	Plant association is somewhat degraded or recovering. While species diversity is typically low, environment and species composition are similar to published source.
D Poor	Plant association is degraded by logging, grazing, development, or by non-native species, although it is still recognizable as a described community.
E Extirpated	Plant association is completely altered and unrecognizable. Non-natives dominate.

PROCEDURE FOR ESTABLISHING TRANSECT AND PLOT LOCATIONS

Step 1: In GIS format, or in the field using aerial photographs for reference, establish transects within the acquisition parcel and determine geographical coordinates of the endpoints of each transect. These transects will be termed **"baseline transects"** and their positioning and length will be determined on a site-by-site basis. The precise location of these transects may be adjusted as they are established in the field, based on the characteristics of the terrain and vegetation. Transects need not be established in all vegetation polygons, but must be established in all major vegetation types. Install a steel rebar stake at the transect origin. To facilitate relocating the origin stake, metal identification tags may be attached with aluminum nails at eye level to adjacent trees, if such trees are present, facing the origin stake. The origin stake will be permanently labeled with a metal or plastic cap on the upper end of the rebar. Ability to relocate transect origins is of primary importance, and the location of endpoints may be modified based on landmarks in the field to facilitate relocation. For example, prominent outcrops of trees may be used to mark endpoints. Record GPS coordinates of origin stakes and end points of transects, along with datum used, and include notes and a sketch map on the data sheets to facilitate relocation in the field.
`

After the first field visit, modify the transects in GIS to conform with transects as they are actually established on the ground, and include a sketch map of the transect layout on the Transect Plot Data Sheet. Sampling plots will be randomly located on these transects. Prior to collecting plot data, record the locations of boundaries between major vegetation types by GPS coordinates and in distance along the transect from the transect origin.

For the purpose of characterizing vegetation within polygons, locate plots in homogeneous areas, away from ecotones. If the baseline transect is located entirely within a vegetation polygon, select plots from the entire transect. See Transect A in Figure 12 (page 44). If the baseline transect extends across polygon boundaries, select plots from the portion of the transect within an individual polygon. If the baseline transect crosses narrow vegetation bands, as in Transect B in Figure 12, in some cases it may be necessary to establish lateral transects extending off the baseline in order to obtain the required number of random plots. If lateral transects are required, stake and record them in the same manner as the baseline transects. Establish plots by first randomly locating **transect segment starting points** at a minimum interval of 10 meters along the baseline transects. Select five transect segment starting points in each major vegetation type (grassland, shrubland, forest). If there are pronounced differences within a major vegetation type, additional segments may be selected to sample the range of vegetation. Locate transect segment starting points by distance from the origin point along the baseline or lateral transect. On uneven ground it may help to permanently mark segment starting points in the same manner as transect origin points, with rebar stakes and metal tags, but generally distance along the transect will give

a precise location. Locate plots in reference to these transect segment starting points, depending on the type of vegetation, as described below.

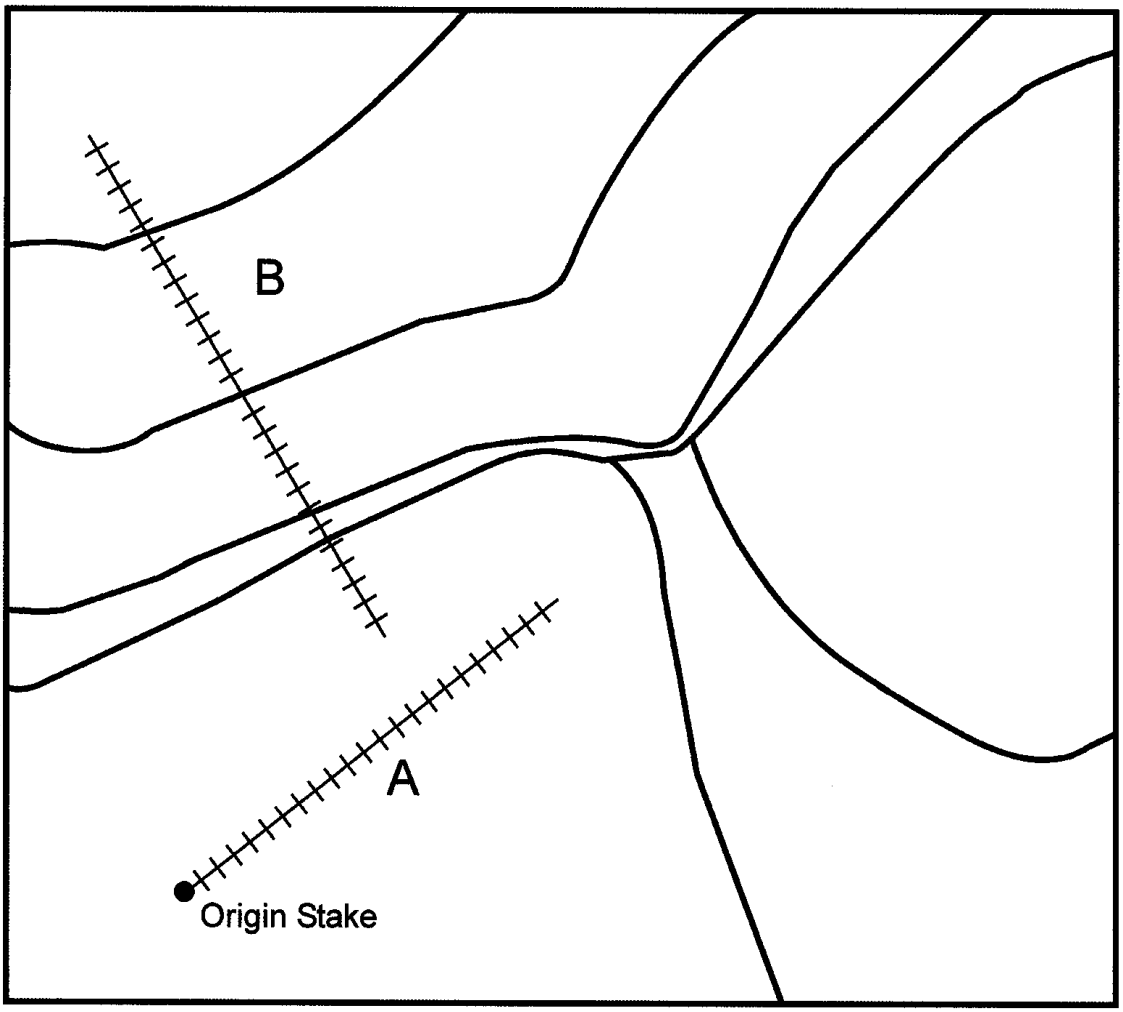

Figure 12. Diagrammatic Vegetation Polygons Showing Transect Locations.

Step 2: If the area surveyed is grassland, proceed with Step 3. If the area surveyed is sagebrush, steppe, or other shrubland, proceed to Step 8. If the area surveyed is forested, proceed to Step 12. If a project area includes two or more vegetative types, locate each transect segment to lie within a single vegetation type.

GRASSLAND PLOTS

Step 3: Establish plots as 1 meter segments of the baseline transect extending for 10 meters beyond each designated transect segment starting point.

Step 4: Mark the outer boundaries of the transect segment. The transect segment starting point has been established and marked in Step 1 above. Mark the other end of the segment at 10 meters along the transect by installing and marking a 0.5 in. rebar stake. Burial of the stakes is recommended to avoid vandalism.

Step 5: Depending on the visibility and the vegetation, take a photo of the transect segment from a lateral view, or other feasible point of view, to obtain a community-wide view of change over time.

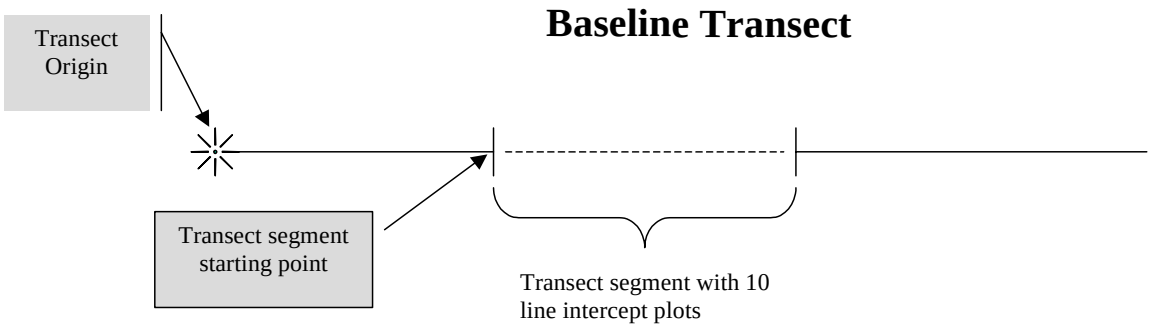

Figure 13. Establishing a Transect Segment

Step 6: On the transect plot data sheet, record each species that touches the line and measure in centimeters the extent of the species intersection with the line. Record the substrate (bare soil, mosses, lichens, rock, forest litter, basal area, etc.). These values should add up to 100 percent. Basal area is the area of the cross section of living plants. Record average height by vegetation type within each plot.

Step 7: Repeat Steps 3-6 for each grassland transect segment sampled.

SHRUB PLOTS

Step 8: Establish transect segment starting points. As described above for grassland plots, each transect segment starting point will be a random point that has been established along the baseline transect, at minimum intervals of 10 meters. Establish ten 1-meter plots on each transect segment, extending for 10 meters beyond each designated transect segment starting point. If practical, run the tape along the ground. However, if the shrubs are tall and fairly continuous, it may be necessary to string the tape at an elevated location through the stems. Record the method of stringing the tape so future monitors can replicate your work.

Step 9: Depending on the visibility and the vegetation, take a photo of the transect segment from a lateral view, or other feasible point of view, to obtain a community-wide view of the vegetation, with the intention of recording change over time.

Step 10: On the transect plot data sheet, record each species that touches each 1-meter transect segment plot and measure in centimeters the extent of the species intersection with the line. Record the substrate (bare soil, rock, mosses, lichens, forest litter, basal area, etc.).

Step 11: Repeat Steps 8-10 for each shrubland transect segment sampled.

TRANSECT PLOT DATA SHEET			Project:					Date:		
Surveyors:			Transect #				Transect Heading:			
GPS Datum:			Origin Stake GPS Coordinates:							
Transect Segment Starting Point (in meters from the Origin Stake):										
species	Plot Number									
	1	2	3	4	5	6	7	8	9	10
Moss/lichen cover										
Average height shrubs (cm)										
Average height herbs (cm)										

Figure 14. Herbaceous and shrub transect data sheet

FOREST PLOTS

Protocol adapted from: ***New Zealand National Vegetation Survey (2004); Greening Australia Federation (2004); Wishnie et al. (1999)***

Step 12: Establish a 1/10 acre circular plot centered over each transect segment starting point. These points have been established and marked in Step 1 above. Permanently mark the center of each forested plot by installing a 0.5" rebar stake, and marking it with a metal identification tag.

Step 13: Measure out 37.2 feet in all directions from the center stake. For each plot, record the following data on the Forest Plot Data Sheet:

a. Project site, plot number, and date.
b. Tree species.
c. Height or diameter at-breast height (DBH), 4.5 feet from the ground, of each tree by the following size classes. Basal area (square feet per acre) and stem density (number per acre) will be calculated from this plot data. Trees less than 4.5 feet tall will be recorded as seedlings and will not be included in the calculation of stems per acre.

DBH

1) 0.0" – 2.5" = 1
2) 2.6" – 5.0" = 2
3) 5.1" – 10.0" = 3
4) 10.1" – 15.0" = 4
5) 15.1" – 20.0" = 5
6) 20.1" – 25.0" = 6
7) >25.0" = 7

Step 14: Record shrub and herbaceous species in each of the ten one-meter plots following the transect segment starting point, as described above in the protocol for grasslands, Steps 3-7.

Step 15: Repeat Steps 3-7 (for grasslands), 8-11 (for shrublands), and 12-14 (for forested stands) in year 3, 6, 9, and 12.

FOREST PLOT DATA SHEET		Plot Number: (transect/plot center)					
Project:		Date:					
Surveyors:		Transect #			Transect Heading:		
GPS Datum:		Origin Stake GPS Coordinates:					
Plot Center (meters from the Origin):		Slope (%):			Aspect (degrees):		
tree species	seedlings (< 4.5' tall)	tree size class (dbh in inches)					
		<6	6-12	12-24	24-36	36-48	>49

Figure 15. Forest Plot Data Sheet

METHOD FOR DETERMINING INTERTIDAL CONDITIONS

Protocol provided by: ***Joseph Arnett of Tetra Tech FW, Inc. with parameters taken from NOAA Coastal Ocean Program "Science Based Restoration Monitoring Of Coastal Habitats"***

PURPOSE

Many SRFB acquired lands contain significant areas of intertidal habitat that either were acquired in fee title or by easement to protect the marine portion of the estuary where juvenile salmon reside. These protocols are intended to track marine vegetation in the form of marine algae and rooted vascular plants in terms of species diversity, and density as a measure of their health and changes since the base year when purchased. Beach slope and percent fines will also be monitored as indicators of changes in beach physical conditions.

EQUIPMENT

Topographic maps, ESRI Arc View or ArcMap software with appropriate laptop or desktop computer, aerial orthophotographs (taken at low tide, if available) digital camera, tripod, compass, hand held GPS unit, engineering flagging tape, 2 ft. rebar stakes, forestry marking paint, magnetic field locator for surveys in years subsequent to the initial layout, plot identification tags, wire, clipboard and pencils, standard plant press, containers for plant samples, plant identification guides, 50 meter tape, small gardening trowel, tally meter, appropriate waterproof field forms.

SAMPLING DURATION

Sampling should occur during the summer when the majority of estuarine and marine rooted vascular plants are in full growth and when the tide is at a minus stage. This time period may change from year to year depending on tides.

PROCEDURE FOR DELINEATING VEGETATION POLYGONS

Step 1: Obtain orthophotographs of all marine acquisitions to be sampled.

Step 2: For each acquisition delineate major vegetation polygons in the intertidal zone by visual inspection of the orthophotos in GIS format (Arc View or ArcMap). The level of resolution of this delineation depends on the type of vegetation, but would, at a minimum, distinguish between algae, cordgrass, kelp, and eelgrass communities. Vegetation polygons in the estuarine environment are often distinct and based on dominance of a single species.

PROCEDURE FOR FIELD EVALUATING VEGETATION POLYGONS

Step 1: During the field survey verify the boundaries of the vegetation polygons as delineated in GIS.

Step 2: Classify and assess the vegetation within the polygon using the field data form. Plant associations will be based on the best available classifications. If existing classifications are not applicable the vegetation will be characterized by the dominant species in each vegetation layer. The source of the classification will be included in the data.

Step 3: During field examination, representative polygons will be examined for vegetation history, based on conditions in the field and augmented with information obtained from local land managers, if available.

Step 4: The following information will be recorded for representative polygons on Polygon Vegetation Data Sheets (Figure 11) for each of the identified polygons:

- Survey intensity
- Total percent cover of algae, kelp, and eel grass
- The most abundant species in each life form category
- Percent fines.
- Land use, including, industrial, aquaculture, development, wildlife use, and recreation type and severity.
- All plant associations encountered in each polygon, or dominant species, with list sources of plant associations.
- Estimation of percent of each plant association in each polygon
- Pattern of distribution of each plant association in the polygon.
- Brief comments about each plant association
- Remarks about the polygon as a whole, including information on the presence of exotic species, incidental observations of rare plants, or other sensitive or unique features, and preliminary management recommendations.

PROCEDURE FOR ESTABLISHING TRANSECT AND PLOT LOCATIONS

Step 1: In GIS format, establish transects perpendicular to the slope, extending from the upper limits of vegetation influenced by extreme high water across the intertidal zone to the level of mean low tide. Determine geographical coordinates of the transect origin and endpoint of each transect. These transects will be termed **"baseline transects"** and their positioning will be determined on a site-by-site basis. For the purpose of characterizing intertidal substrate and vegetation, as well as vegetation within the area of influence of extreme high water, **"transect segments"** will be randomly located in homogenous polygons along these baseline transects. If vegetation polygons are too narrow to allow an adequate number of 10-meter transect segments within homogenous areas, **"lateral transects"** may be established parallel to the polygon boundaries, as illustrated in Figure 16. Install a steel rebar stake at the transect origin. To facilitate relocating the origin stake metal identification tags may be attached with aluminum nails to adjacent trees, if such trees are present, facing the origin stake. The origin stake will be permanently labeled with a metal or plastic cap on the upper end of the stake and a metal identification tag at ground level. Ability to relocate transect origins is of primary importance. GPS coordinates of transect origin and transect segment starting points will be recorded, along with datum used. The number of segments along the baseline transects will depend on the variation within the vegetation, but an average of 5 transect segments within each major vegetation type at each project area is anticipated. Prior to sampling within transect segments, record the locations of boundaries of major changes in vegetation along baseline transects. Include boundaries between vegetation and bare ground and between substrate classes. Record boundaries by distance along the transect from the origin point and by recording GPS coordinates.

Step 2: Each transect segment starting point will be a random point that has been established along the baseline transect, at minimum intervals of 10 meters (Figure 16). Ten **plots** will be established on each transect segment, extending for 10 meters beyond each designated transect segment starting point.

Step 3: Mark the transect segment dimensions by installing 0.5 inch rebar stakes at the segment staring point and at 10 meters along each transect segment. Burial of the origin stake is recommended to avoid vandalism.

Step 4: Color code transect segment beginning and ending stakes (orange for origin point and blue for end point) with forestry marking paints. Install permanent transect segment identification tags on each stake.

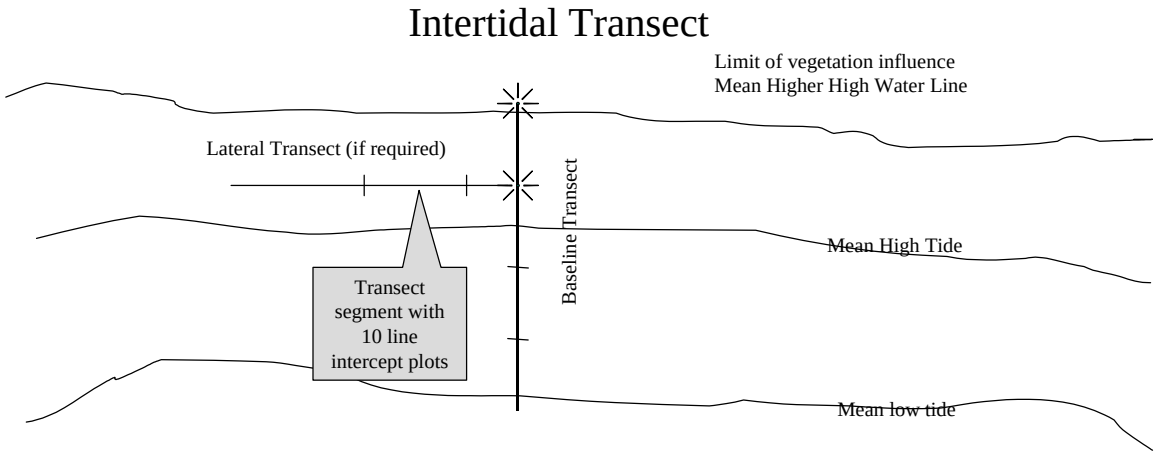

Figure 16. Establishing an Intertidal Transect Segment

Step 5: Within each 1-meter plot, record each species that touches the transect segment line and enter the information on the appropriate data sheet (Figure 14 or 15). Record the species from the tallest to the shortest. For portions of plots devoid of vegetation, record the substrate as fines, sand, or gravel. Average height by vegetation type will be recorded within each plot.

Step 6: Repeat Steps 3-5 for each transect segment.

TESTING FOR SIGNIFICANCE

A random sample will be drawn without replacement from completed SRFB habitat protection projects and monitored for the above response indicators to test the null hypotheses. We must be sure that the sample size is large enough to detect significant changes in the response indicators over a relatively short period of time. The number of projects that must be sampled is dependent upon the amount of variation from year to year and among projects, the signal to noise ratio, and the power of the test. Existing data from EMAP sampling conducted by the USEPA and Oregon Department of Fish and Wildlife were used to estimate minimum sample sizes needed to detect change.

A simple linear regression model was used to estimate the number of sites needed to determine whether stream locations improve or decline in condition through time. For this model, each habitat variable would be regressed against year. A slope significantly different from zero would indicate a change in resource condition, with improvement indicated by a positive slope and decline by a negative slope. The linear model assumes that the response variable is normally distributed.

For each variable, the model can be expressed in terms of an equation =M. In the case of RP100 where

$$RP100_{sy.} = M + S_s + Y_y + E_{sy}$$

and RP100 for a particular site-visit differs from the mean of all site-visits (M) based on the site location, S (indexed from 1 to the total number of sites), and year, Y (with *y* indexed by year). E_{sy} represents the residual, or unexplained, variance due to measurement error.

The significance of the trend, or slope of the line, depends on its associated variance (Larsen et al. 1995; Urquhart et al. 1998). If the response variable is extremely variable, only very large changes in the slope will be statistically significant. The smaller the variance associated with the slope of the trend line, the more likely we are to detect significant changes. To estimate the variance of the slope, the following equation was used:

$$\text{var}(\hat{C}) = \frac{s^2_{year} + (s^2_{site*year} + s^2_{error})/s}{\sum (Y_y - \ddot{Y})^2}$$

where $\hat{C}$ represents the slope, s^2 refers to an estimate of variance, *s* equals the number of sites, and *r* equals the number of repeat visits to each site. In the denominator, *Y* represents the year value indexed according to the number of years sampled. Data from Oregon Department of Fish and Wildlife and the EPA's Regional Environmental Monitoring and Assessment Program (REMAP) in Washington and Oregon was used to estimate variance components for this model (D. P. Larsen, personal communication).

Slope estimators are assumed to be normally distributed. We used the estimate of the slope's variance above in the following equation to estimate the statistical power of a habitat variable to detect changes through time:

$$\text{Power} = \Phi \left[z_\alpha - \hat{C} / \text{s.e.}(\hat{C}) \right]$$

Power was set to equal to 0.8, Φ is the cumulative normal distribution function, z_α was equal to 0.10 for a 1-sided test, and the standard error of the slope [*s.e.* ($\hat{C}$)] was derived from the equation above. The equation was solved for $\hat{C}$, the slope, to determine the minimum amount of change a habitat variable could detect.

Different sampling scenarios were evaluated using this approach by varying the number of sites and years sampled. This process was completed for all habitat variables to determine the best overall

sampling strategy for each variable. Statistical testing for a slope different from zero will determine whether the projects improved, declined, or showed no change through time. After three years of data collection, individual sites can also be tested for improvement, decline, or no change in biological condition.

An example regression may look similar to Figure 17.

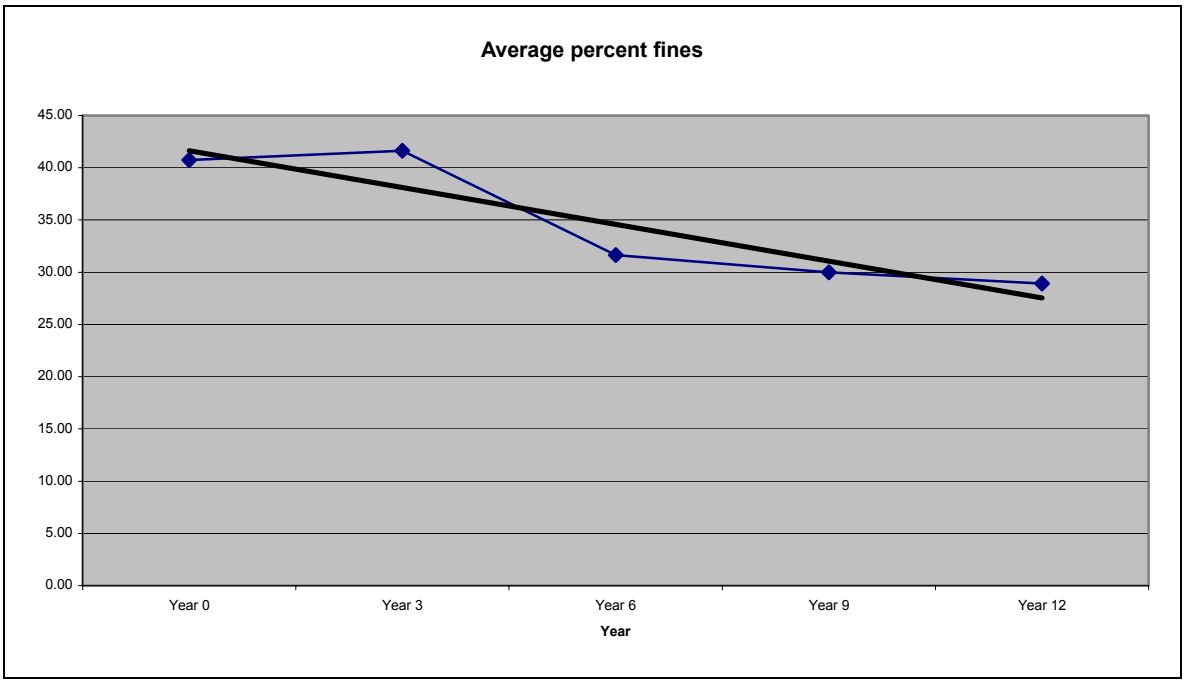

Figure 17. Sample regression chart of percent fines (each data point represents average of 10 projects)

Table 7. Sample size (sites) and years needed to detect 10% and 20% change in selected indicators. Table provided to demonstrate why a sample size of ten was chosen for various project categories.

Indicator	# Sites	10% Change	20% Change
XEMBD	10	6-9 years	3-6 years
	20	6-9 years	3-6 years
PCTFN	10	6-9 years	3-6 years
	20	6-9 years	3-6 years
XCDENBK	10	6-9 years	3-6 years
	20	6-9 years	3-6 years
	30	3-6 years	3-6 years
RP100	10	12-20 years	9-12 years
	20	12-20 years	9-12 years
LWD	10	6-9 years	3-6 years
	20	6-9 years	3-6 years
	30	3-6 years	3-6 years
XDEPTH	10	>20 years	12-20 years
	20	>20 years	12-20 years

Based upon the results shown in Table 7, ten acquisition projects will be sampled five times over 12 years (Years 1, 3, 6, 9, and 12) in order to detect a 20% change in the variables. For nearly all variables,

increasing the number of sites from 10 to 20 had no effect upon the ability to detect change in a shorter period of time or in increasing the amount of change that could be detected.

REFERENCE YEAR

Studies designed to compare the quality of habitat sometimes use reference locations. Reference locations contain habitat considered ideal, or representative of, natural conditions. They are used as a point of reference for comparing changes in the habitat for the lands being monitored. Because the lands sampled are so varied, and because most available reference areas in Washington are higher elevation sites, a baseline year will be used for reference for each of the sampled properties. Change will be measured against the baseline year. Baseline years will be established as soon as a property is acquired, whenever possible, in order to reflect the status of the property at the time it was acquired.

EVALUATION OF CHANGE AT INDIVIDUAL SITES

Although the above information has value in testing whether acquisitions in general have or have not maintained their habitat characteristics as measured by the indicators, it is of minimal value in evaluating effectiveness of individual parcels in maintaining their habitat characteristics over time. However, after three or more years of sampling, a regression may be performed to provide additional information.

GOAL

The goal is to test for changes in individual parcels through time using 15 habitat variables measured at a site. In order to compare all variables simultaneously for two sampling occasions at one site, a single statistical test is needed.

METHOD

One approach would compare each of the 15 variables for the initial sampling time with the most recent sampling time (that is, only the first and last samples would be compared). If the variables are independent (see below), we would conclude no change if about half the variables indicated improved conditions while the other half indicated a decline. Thus, we would like to test if the probability of change is significantly different from 50% (p = 0.5). A two-tailed binomial test will test whether the number of variables that changed is different from what we would expect due to chance alone.

The sign test is a robust nonparametric test that is an alternative to the paired *t*-test. This test makes the basic assumption that there is information only in the signs of the differences between paired observations, not in their sizes. If the value represents a positive change to the better or no change for habitat or fish and invertebrate assemblages, a + is given, and for the opposite case where there is an observed decline in the variable, a – is given. The null hypothesis is that the probability of a variable being + or – is 0.5

We will take the paired observations, calculate the differences, and count the number of +s n_+ and –s $n\_$, where $N = n_+ + n\_$ is the sample size. We will use tables provided by Zar (1985) which gives the $n\_$, probability of getting exactly this many +s and -s if positive and negative values are equally likely.

Table values from Zar (1984) illustrate the changes that would be significant for 12, 13, 14 or 15 habitat variables (Table 1).

ASSUMPTIONS

Habitat measures at a site are not necessarily independent. Residual pool depth may be related to bankfull depth. While it is probably not possible to select a set of completely independent habitat measures, a reasonable effort should be made to eliminate those that depend directly on each other to make this a fair test. The test is equivalent to a coin toss for each variable. If an increase in one variable predicates an increase in another, they are not independent and the “coin toss” is biased.

Table 8. Table values for testing whether the number of variables is statistically significant (two-tailed binomial test, P = 0.5). Shown are the number of habitat variables measured at a site, the number of variables that improved vs. declined (or declined vs. improved) when the first year of sampling was compared to the last year, and the *p*-value associated with that level of change. Example: "For 12 measured habitat variables at a site, if 10 of 12 variables improve (or 10 of 12 variables *decline*), we conclude that site condition has improved (or *declined*) with a confidence of p < 0.10." Values are from Table B.26 in Zar (1984).

Number of variables	Ratio of change	p
12	10 vs. 2	< 0.05
12	11 vs. 1	< 0.01
12	12 vs. 0	< 0.001
13	11 vs. 2	< 0.05
13	12 vs. 1	< 0.005
13	13 vs. 0	< 0.001
14	12 vs. 2	< 0.02
14	13 vs. 1	< 0.002
14	14 vs. 0	< 0.001
15	12 vs. 3	< 0.05
15	13 vs. 2	< 0.01
15	14 vs. 1	< 0.001
15	15 vs. 0	< 0.001

Table 9. Example table for testing overall percent positive change in measured indicators at a parcel.

Project #1	Year 1 2003	Year 3 2005	Plus or Minus
	Baseline	After	
AREASUM	51	49	-
RP100	1.5	1.4	-
Log10(V1WM)	29	19	-
XCDENBK	13	15	+
XPCMG	78	76	+
MMI INVERT	3	3.2	+
FISH IBI	4.4	4.8	+
XEMBD	18	17	+
PCT_FN	12	13	-
BANK	8	9	-
CHANL			
GRASS	12	16	+
SHRUBD	30	40	+
SHRUBSD	25	29	+
DTREE	20	20	+
Total +			9
N			15
P Value			90
Accept Hyp			No

DECISION CRITERIA

Table 10. Response variable decision criteria

Habitat	Indicators	Metric	Test Type	Decision Criteria
Riparian Condition	Mean percent canopy density at the bank densitometer reading (XCDENBK)	1-17 score	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 0 and Year 3, 6, 9, or 12
	3-layer riparian vegetation presence (proportion of reach) (XPCMG)	%	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 0 and Year 3, 6, 9, or 12
	Actively eroding banks (BANK)	%	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 0 and Year 3, 6, 9, or 12
Stream Morphology	Mean residual pool vertical profile area (AREASUM)	m^2	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 10
	Mean residual depth (RP100)	cm	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 0 and Year 3, 6, 9, or 12
	Percent substrate embedded (XEMBED)	%	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 0 and Year 3, 6, 9, or 12
	Percent substrate as fines (PCT_FN)	%t	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 1 and Year 3, 6, 9, or 12
	Large Wood (Log10(V1WM100)	m^3	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 1 and Year 3, 6, 9, or 12
	Mean bank full cross sectional area taken from mean bank full width and height (CHANL)	Ave. m^2	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 5% change between Base Year 1 and Year 3, 6, 9, or 12
Stream Animal Assemblages	Macroinvertebrate Multimetric Index (MMI INVERT)	MMI score	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 1 and Year 3, 6, 9, or 12
	Fish species Assemblages (FISH INDEX)	FI score	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 1 and Year 3, 6, 9, or 12
Upland habitat	Percent cover of non-native vascular plant species (HERB_NN)	%	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 1 and Year 3, 6, 9, or 12

Habitat	Indicators	Metric	Test Type	Decision Criteria
	Percent cover of non-native shrub species (SHRUB_NN)	%	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 1 and Year 3, 6, 9, or 12
	Basal area of conifers per acre (BA_CONIF)	ft^2/acre	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 1 and Year 3, 6, 9, or 12
	Stem count of conifers per acre (SA_CONIF)	#/acre	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 1 and Year 3, 6, 9, or 12
	Basal area of deciduous trees per acre (BA_DECID)	ft^2/acre	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 5% change between Base Year 1 and Year 3, 6, 9, or 12
	Stem count of deciduous trees per acre (SA_DECID)	#/acre	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 5% change between Base Year 1 and Year 3, 6, 9, or 12
Intertidal Habitat	Percent cover of algae per transect (ALGAE_M)	%	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 5% change between Base Year 1 and Year 3, 6, 9, or 12
	Percent cover of nonnative herbaceous vascular plants (VASCULAR_NNM)	%	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 5% change between Base Year 1 and Year 3, 6, 9, or 12
	Percent slope from mean high tide to mean low tide (SLOPE_M)	%	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 5% change between Base Year 1 and Year 3, 6, 9, or 12
	Mean percent of the substrate transect in fines (PCT_FNM)	%	Linear Regression Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 5% change between Base Year 1 and Year 3, 6, 9, or 12

AFTER-PROJECT DELIVERABLES

The monitoring entity will deliver to the SRFB on Year 3, 5, and 10:

- A completed copy of all monitoring data
- A completed metadata form
- Percent change in upland vegetation composition
- Percent change in riparian vegetation composition
- Percent change in amount of stream shaded
- Percent change in stream gravel fines
- Percent change in stream Thalweg profile measures
- Percent change in actively eroding streambanks
- Percent change in macro-invertebrate MMI
- Percent change in fish MMI
- A statement as to whether Decision Criteria were met as effective habitat protection projects

QUALITY CONTROL

For 5% of the monitored parcels, a different sampling entity will collect the same data to verify results.

DATA MANAGEMENT PROCEDURES

Data will be collected in the field using various hand-held data entry devices. Raw data will be kept on file by the project monitoring entity. A copy of all raw data will be provided to the SRFB at the end of the project. Summarized data from project analysis will be downloaded to the PRISM database. The PRISM database shall contain fields for the response variables associated with these objectives.

AUDITS AND REPORTS

TECHNICAL SYSTEMS AUDIT (TSA)

The SRFB will employ a consultant to randomly audit 5% of ongoing acquisition monitoring to determine if quality assurance protocols and procedures are followed. This audit should be completed annually, shortly after the monitoring of parcels begins.

PROGRESS REPORT

A progress report will be presented to the SRFB in writing by the monitoring entity after the sampling season for Year 1 and Year 5.

FINAL REPORT

A final report will be presented to the SRFB in writing by the monitoring entity after the sampling season for Year 10. It shall include:

- Estimates of precision and variance
- Confidence limits for data
- Summarized data required for PRISM database
- Determination whether project met decision criteria for effectiveness
- Analysis of completeness of data, sources of bias

Results will be reported to the SRFB during a regular meeting after 3, 6, 9, and 12 years of sampling. Results will be entered in the PRISM database and will be reported and available over the Interagency Committee for Outdoor Recreation web site and the Natural Resources Data Portal.

ESTIMATED COST

It is estimated that between 157 and 210 hours would be required for each acquisition project, depending on size and location of the parcel. Costs for each project range from $12,000 to $19,000.

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APPENDIX 1

VARIANCE ESTIMATES PROVIDED BY PHIL LARSON FOR EMAP SAMPLING IN OREGON AND WASHINGTON

Indicator	site	year	interaction	residual
NorthCoast				
GRADIENT (%)	18.355	0.158	0.000	1.456
WIDTH (meters)	16.290	0.000	0.587	0.474
ACW (meters)	54.023	2.241	2.968	1.768
ACH (meters)	0.215	0.001	0.003	0.014
UNITS100 (#/100 meters)	3.133	0.215	0.000	1.451
NOPOOLS (per surveyed reach)	33.074	0.346	0.000	61.724
POOLS100 (#/100 meters)	0.748	0.095	0.000	0.739
PCTPOOL (%)	547.034	33.415	134.101	79.949
PCTSNDOR (%)	639.270	13.579	0.000	65.795
PCTGRAVEL (%)	124.711	5.676	0.000	62.562
RIFSNDOR (%)	565.694	14.888	0.000	109.893
RIFGRAV (%)	163.597	28.215	0.000	129.284
SHADE (%)	218.243	1.317	27.478	68.804
LOG(PIECESLWD + 0.01) (#/100m)	0.763	0.000	0.184	0.157
LOG(VOLUMELWD +0.01) (m^3/100m)	0.782	0.014	0.110	0.343
RESIDPD (meters)	0.041	0.000	0.007	0.009
MidCoast				
GRADIENT	29.113	0.013	0.000	0.268
WIDTH	23.326	0.044	0.002	0.240
ACW	36.874	0.000	0.000	1.536
ACH	0.030	0.005	0.002	0.009
UNITS100	3.241	0.394	0.194	1.790
NOPOOLS	79.058	6.550	2.245	42.350
POOLS100	0.594	0.155	0.277	0.703
PCTPOOL	523.901	7.683	45.339	58.514
PCTSNDOR	273.350	6.282	61.548	40.020
PCTGRAVEL	118.169	0.000	72.143	43.067
RIFSNDOR	122.774	9.892	122.051	20.380
RIFGRAV	147.421	16.788	111.854	103.025
SHADE	101.627	0.000	0.000	72.149
LOG(PIECESLWD + 0.01)	0.576	0.000	0.053	0.071
LOG(VOLUMELWD +0.01)	1.179	0.082	0.019	0.137
RESIDPD	0.024	0.002	0.002	0.003

Indicator	site	year	interaction	residual
MidSouth Coast				
GRADIENT	39.323	0.000	0.668	1.127
WIDTH	11.787	0.140	0.265	0.445
ACW	127.226	0.284	13.844	1.469
ACH	0.067	0.008	0.041	0.010
UNITS100	3.617	0.000	0.000	2.757
NOPOOLS	40.158	7.783	0.000	39.949
POOLS100	0.994	0.130	0.000	0.936
PCTPOOL	2302.291	66.942	0.000	133.292
PCTSNDOR	745.841	0.000	50.251	38.813
PCTGRAVEL	154.449	14.949	99.921	42.448
RIFSNDOR	596.811	0.000	0.000	97.845
RIFGRAV	245.749	57.324	121.386	143.471
SHADE	359.391	0.000	36.755	36.033
LOG(PIECESLWD + 0.01)	1.841	0.053	0.061	0.144
LOG(VOLUMELWD +0.01)	2.526	0.000	0.130	0.142
RESIDPD	0.060	0.001	0.000	0.057
South Coast				
GRADIENT	48.931	0.009	0.000	0.819
WIDTH	5.861	0.000	0.148	0.320
ACW	0.925	0.152	1.323	1.178
ACH	0.034	0.000	0.000	0.024
UNITS100	3.966	0.228	0.276	2.114
NOPOOLS	23.026	5.504	17.710	7.287
POOLS100	0.465	0.169	0.535	0.169
PCTPOOL	134.038	3.604	63.489	14.255
PCTSNDOR	310.631	1.362	50.100	31.698
PCTGRAVEL	98.312	1.365	3.740	59.004
RIFSNDOR	239.329	3.144	27.204	26.771
RIFGRAV	141.190	1.956	0.000	147.734
SHADE	242.543	0.099	0.004	34.122
LOG(PIECESLWD + 0.01)	1.266	0.013	0.000	0.113
LOG(VOLUMELWD +0.01)	2.560	0.012	0.488	0.128
RESIDPD	0.076	0.001	0.000	0.009
Umpqua				
GRADIENT	38.669	1.468	1.028	0.707
WIDTH	5.371	0.027	0.200	0.181
ACW	14.712	0.109	0.000	1.415
ACH	0.009	0.000	0.000	0.019

Indicator	site	year	interaction	residual
UNITS100	4.328	0.305	1.019	1.939
NOPOOLS	42.423	4.043	4.984	15.272
POOLS100	0.787	0.181	0.574	0.460
PCTPOOL	370.002	11.894	37.765	28.533
PCTSNDOR	390.854	5.954	0.000	52.316
PCTGRAVEL	133.923	17.369	0.000	69.735
RIFSNDOR	419.849	3.834	0.000	102.846
RIFGRAV	184.520	32.025	0.000	191.116
SHADE	43.049	52.844	70.674	117.949
LOG(PIECESLWD + 0.01)	0.636	0.006	0.000	0.404
LOG(VOLUMELWD +0.01)	1.579	0.000	0.994	0.152
RESIDPD	0.040	0.003	0.004	0.004
All				
GRADIENT	35.043	0.141	0.782	2.673
WIDTH	12.729	0.011	0.412	0.664
ACW	53.292	0.024	0.000	6.488
ACH	0.075	0.000	0.011	0.016
UNITS100	3.512	0.196	0.109	2.407
NOPOOLS	46.746	2.061	0.000	43.968
POOLS100	0.758	0.104	0.011	0.878
PCTPOOL	766.630	7.196	50.633	138.567
PCTSNDOR	445.890	0.648	36.730	100.554
PCTGRAVEL	129.336	1.087	28.487	68.083
RIFSNDOR	349.322	2.656	14.741	143.852
RIFGRAV	183.849	7.594	55.597	156.896
SHADE	195.289	3.425	16.858	80.223
LOG(PIECESLWD + 0.01)	1.048	0.012	0.000	0.258
LOG(VOLUMELWD +0.01)	1.722	0.003	0.202	0.429
RESIDPD	0.049	0.001	0.000	0.019
Relative variances for All				
GRADIENT	0.906944	0.00364	0.02024	0.069176
WIDTH	0.92134	0.000765	0.029812	0.048083
ACW	0.891119	0.000394	1.87E-10	0.108487
ACH	0.733491	4.23E-06	0.108201	0.158303
UNITS100	0.564281	0.031513	0.017529	0.386676
NOPOOLS	0.503861	0.02222	2.14E-07	0.473918
POOLS100	0.432636	0.059638	0.006326	0.501401
PCTPOOL	0.796064	0.007472	0.052577	0.143887
PCTSNDOR	0.763743	0.001111	0.062912	0.172234

Indicator	site	year	interaction	residual
/..PCTGRAVEL	0.569778	0.004791	0.125497	0.299935
RIFSNDOR	0.684179	0.005202	0.028872	0.281747
RIFGRAV	0.455143	0.018801	0.137639	0.388418
SHADE	0.660218	0.011578	0.056992	0.271211
LOG(PIECESLWD + 0.01)	0.795269	0.008767	3.88E-13	0.195964
LOG(VOLUMELWD +0.01)	0.730982	0.00115	0.085641	0.182227
RESIDPD	0.703577	0.01681	3.78E-14	0.279613